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CONTROL DATA
CORPORATION

A SYSTEM STUDY OF A FIRE DANGER MONITORING NETWORK

FINAL REPORT

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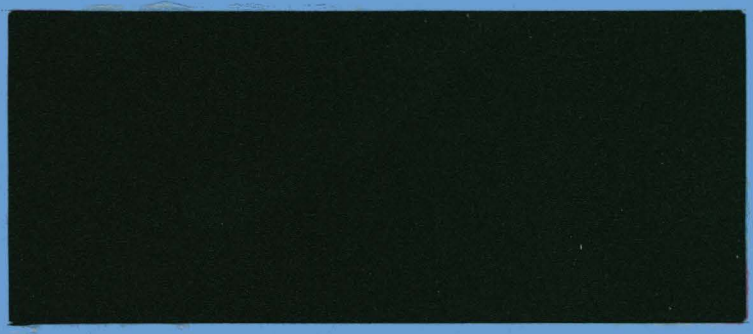

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ROCKY MOUNTAIN STATION

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INTRODUCTION

This study and report essentially constitute a plan for a system study of a nationwide fire danger monitoring network. This network is to be deployed throughout the forests managed by the United States Forest Service so as to gather the necessary data to permit the real-time calculation of forest fire danger indices.

The present report attempts to define the system concepts associated with each element of the data gathering network and the corresponding physical functions required. It is intended that these results form the basis of a more detailed system study, referred to in the report as Phase II.

Part I of the report describes briefly several data acquisition networks similar in concept to the subject network and indicates a sampling of commercial equipment now available which is similar to that which will be required for the present network. Part II of the report discusses the functional requirements and alternatives of the network implementation. A schedule of tasks and required system definitions for Phase II is then presented. Additional study items considering particular hardware are included in the next part of the study as a proposed task schedule for Phase III. A later report section lists the items to be considered in estimating the cost of system development, deployment, and maintenance. The bibliography includes nearly all the references consulted during the course of the present work and also those which promise to be of use during the Phase III portion of the study.

PART I EVALUATION OF EXISTING SYSTEMS

A. COLUMBIA RIVER OPERATIONAL HYDROMET MANAGEMENT SYSTEM (CROHMS)

This system represents an attempt to consolidate the hydrological and climatological data facilities in the Pacific Northwest to allow for efficient collection of the data and its use by many interested agencies. The seven Federal agencies presently involved are the Corps of Engineers, Bonneville Power Administration, Bureau of Reclamation, Geological Survey, Forest Service, National Weather Service, and the Environmental Protection Agency. The land area covered measures approximately 500 by 600 miles, comprised essentially of the states of Washington, Oregon, and Idaho. This area includes several existing data networks and computing facilities which will be amalgamated into the larger system.

Table 1 shows the approximate number of remote data stations of various types which will eventually be employed in the CROHMS system.

Table 1. Types of CROHMS Remote Stations

Station Category	No. of Stations	Nominal Update Frequency	No. of Station Parameters	Total Parameters Daily
Streamgaging	230	6 hour	4	3,660
Lakes, Reservoirs	87	6 hour	5	1,750
Climatologic	230	6 hour	4	3,660
Snow Measure	130	daily	1	130
Totals	677			7,000

Because climatological stations share sites with other type stations, only 510 separate station sites will be involved. The great majority of the data is presently gathered by manual means, although plans have been generated for the

automation of several networks, as will be discussed. The extensive data management system has been studied and is at the contract stage. Several large computers are presently used in the member agencies; these will continue to be required for the purposes of power generation control, river basin mathematical modeling, forecasting, flood control, and the operation of multiple conversational consoles. The present microwave network of the Bonneville Power Administration and the extensive Columbia Basin Teletype Circuit will be expanded to form the backbone of the CROHMS communications system.

The present plans for automation of data collection are just being developed, such that a detailed discussion of the equipment to be used cannot be included. The following networks will operate as automated subsystems of the overall collection effort.

1. Wynoochee Automated Network

This network includes the Wynoochee Basin and the Mud Mountain Dam and Howard Hanson Dam areas. Included as remotes are four precipitation stations, three meteorological stations, one snow station, and twelve stream and reservoir gage stations. These have a daily polling frequency which can be increased during flood threats. Communication links to be employed include both microwave and VHF radio.

2. Willomette Basin Automated Network

This network is planned to include fifty stream gages, twenty-five precipitation stations, sixteen reservoir stations, seven climatological stations, and twelve snow stations. Snow data is taken at daily intervals and climatological data is sampled every six hours, while the remaining data is recorded hourly. Consideration is being given to variable polling rate algorithms in which the central computer would vary the polling rate on selected stations in response to the received data. Data transmission will be effected by the backbone microwave link together with VHF radio equipment, including twenty-one VHF repeaters.

3. Dworshak Dam Network

This system will consist of six stream and water temperature stations, eleven snow climate stations, and one reservoir station. The polling of these stations will be controlled by the central computer, and will be hourly for all stations except snow climate, which will be daily. A VHF radio network with seven repeaters is planned.

4. Libby Dam Network

This system will include twelve stream gage stations, eleven snow climate stations, and one reservoir station. Polling intervals are similar to the preceding descriptions and are under computer control. A combination of microwave links and a VHF network with six repeaters will be used to collect the data.

5. Yakima Project Network

Plans for this system call for the automation of about 20 remote hydromet stations connected to a programmable central controller. A VHF network with three repeaters is planned, along with a UHF link to the control center. Consideration is being given to time sharing the radio network to allow it to perform the functions of voice transmission, supervisory control, and data collection.

6. Central Snake Project Network

About forty remote stations are planned for this area; VHF radio with several repeaters will be required because of the rough terrain. The time-shared use of the radio network by data, voice, and supervisory control equipment is anticipated.

7. Upper Snake Project Network

This system will include about thirty remote stations and will use VHF radio for the transmission of data to a backbone two-channel UHF system. Time sharing of the two UHF channels is expected to allow for hydromet data, supervisory control and data, and voice transmission.

B. THE AUTOMATIC HYDROLOGICAL RADIO REPORTING NETWORK (NEW ENGLAND DIVISION, ARMY CORPS OF ENGINEERS)

The New England Division of the Corps of Engineers designed the "Automatic Hydrologic Radio Reporting Network" in order to optimally operate a comprehensive flood control system consisting of thirty-five flood control dams, thirty-four local protection projects, and four hurricane barriers. The five state network contains forty-one remote reporting stations located in five major river basins and key coastal areas; river, reservoir, and tide levels, wind speed/direction, barometric pressure and precipitation are monitored by the reporting station network. Data messages are transmitted over a radio network containing Microwave, UHF and VHF "backbones" and VHF repeater stations. Any one or all of the remote reporting stations can be interrogated and controlled through the computer controlled center at Waltham, Massachusetts.

The acquisition of data is in real time; the computer directly interfaces the radio telemetry network. Any or all stations may be interrogated, and data printed out in three minutes. The data is processed by the central computer and teleprinter outputs distributed to dam control sites, etc. Several remote recording stations exist within the network; these are capable of interrogating certain remote reporting stations and recording their data without central station assistance.

1. Remote Reporting Station

A sample remote reporting station site contains an equipment shelter which houses the radio transceiver, logic card rack, battery pack and batteries, and some of the sensor hardware; a roof-mounted thermoelectric generator provides emergency power. A sample sensor set (Old Saybrook, Connecticut station) monitors the following parameters, reporting data over the indicated range:

PARAMETER	REPORTING RANGE
Tide Level	00.0 to 35.0 ft. (3 digits)
Wind Velocity	000 to 150 mph (3 digits)
Barometric Pressure	26.00 to 32.00 in/Hg (4 digits)
Wind Direction	000 to 359^{o} (3 digits)

The minimum station data set is a 16 bit message; this provides a single 4 digit BCD readout. The message can be expanded to 128 bits in length by adding plug-in cards at 8 bits/card; this would provide 32 BCD digits, or could accommodate 8 sensors at 4 digits/sensor. Sensors providing digital outputs, or shaft position or variable voltage outputs can be accommodated.

The remote station is capable of recognizing up to ninety-nine different identification codes; control functions at the remote site can be added by plug-in cards.

2. Central Station

An IBM 1130 computer interfaces the radio network at the Waltham control center; the system normally operates in a dedicated mode with the computer automatically scheduling the interrogation of the remote network. Manual inputs can be accepted to acquire data from remote reporting stations. The computer system acquires the data, performs conversions to engineering units, performs computation of river flow, and provides outputs such as plots and teleprinter data. Teleprinter data is used locally and is also distributed to remote locations.

3. Radio Network

The radio network contains a microwave backbone link providing 12 voice channels between the central station at Waltham and a communication hub at Wachusett; UHF/VHF links with 3 voice channel capacity emanate from the hub and terminate at relay centers at Ascutney, Vermont; Goshen, Connecticut, and Cape Code Canal, Massachusetts. Communication between the relay center and the remote reporting station can be via VHF repeaters.

4. Station Interrogation

Two frequency-shift-keyed (FSK) subcarriers are transmitted by the backbone network; one FSK channel is designated as the control channel and transports backbone addressing and commands. The other channel is the data channel carrying (a) remote station addressing; (b) remote reporting station data and (c) teletype (or digital) data.

Two sequences are required to interrogate a remote reporting station ; the first sequence involves transmission of a 8 bit word on the control channel to select a VHF repeater station and establish a radio communication link with the remote reporting station. Secondly, a neutral tone is transmitted from .2 to 2 seconds to activate repeaters and cause a changeover from standby power at the remote reporting station.

The remote address is then transmitted with three tone FSK on the data channel and the remote station receives, checks and compares the address with its designated I.D. If address recognition is successful, all station data is staticized, and the entire message transmitted in a bit serial format. The transmission is repeated four times to ensure reception; the station returns to a standby mode with power removed from all but the receiver. If the remote does not reply, the interrogation would be repeated four times.

C. COOPERATIVE FIRE WEATHER DATA SYSTEM, MACON, GEORGIA (PROJECT THEO)

This data system is associated with a fundamental investigation of meteorological phenomena, particularly fog and cloud behavior at essentially ground level. The system was begun in about 1965 with twenty Berkeley Instrument remote stations. * This station measures seven meteorological parameters, digitizes the results, and puts the output on punched paper tape. There is no provision with these stations for automatic data transmission to a central point. The sampling interval used is ten minutes, although the station is capable of intervals as short as one minute and as long as one hour. About twenty seconds is required to read out the data with the digitizing and paper tape equipment used.

* Now Towner Instruments

The stations are deployed, at the location of state fire towers, on a ten mile grid spacing over an area of about 50 by 50 miles. The test area is located along the Georgia seacoast south of the city of Savannah. Since regular line electrical power is available at the tower sites, battery operation has not been necessary, although the Berkeley station has a battery power option. This network has been kept operating at 14 or 15 sites since the original installation.

In about 1967, the need for faster response instruments and telemetered data collection became apparent. A master station and nine remote stations were purchased from the Environmental Sciences Division of Litton Industries, Inc. This separate system, designated the 512 Litton System, was delivered in late 1968 and installed in 1969. Two way FM radio is used as the communication link and each remote station is polled by the master station at ten minute intervals. The master station includes an Interdata minicomputer. As with the original network, seven parameters are measured, and since the newer equipment is located at the same fire tower sites to allow comparison of data, battery powered operation has not been necessary. The time required for assembling the data and transmitting seven parameters is about five seconds.

The Litton 512 System has been kept operating essentially continuously at seven stations since 1969. Computing facilities at the University of Georgia have been used for archival storage and data manipulation. The present plans for the equipment is to keep the Litton System operating and to redeploy some of the Berkeley devices to gather data at elevated stations, particularly for the study of smoke and fog control. The Macon System has been described in a series of reports entitled Project Theo (see bibliography, references 44 and 58).

D. NATIONAL DATA BUOY DEVELOPMENT PROJECT

The purpose of this project, begun in 1967 by the U. S. Coast Guard, is to deploy automatic marine buoys over the deep oceans, coastal U. S. Waters, and U. S. Great Lakes. The buoys will automatically measure and transmit marine and meteorological data in real time. The buoys would be designed to operate unattended for one year with a low probability of failure. High frequency radio and

satellite relay are being studied for possible use in transmitting the buoy data. The question of frequency allocation by the WARC and the possible interagency sharing of satellites has been the subject of recent studies.

E. GEOLOGICAL SURVEY EARTHQUAKE NETWORK

The number of seismic telemetry stations operated by the National Center for Earthquake Research in the California area has grown from 32 in 1967 to 150 now, and is expected to double in the next year. The final projected size of the California array is uncertain, but numbers between 500 and 1000 stations are being discussed. Two types of data are gathered; seismic data which must be sampled at rates as high as 100 samples per second and earth strain data which is sampled once each ten minutes. The seismic data represents the real time capability of the system and is collected by FM transmission over leased telephone lines for the most part, since the majority of stations are located in populated areas.

F. RAMOS

The Remote Automatic Meteorological Observing System is designed for deployment in remote isolated locations; the design philosophy was to minimize power consumption, maximize reliability under hostile environmental conditions, and to use plug-in and modular construction to facilitate field maintenance and maximize flexibility. The maximum size and weight of field components is specified to permit field installation by two men and maintenance by one man. Two subsystems are used; a base station and up to 25 remote stations interconnected by a communications link. The remote station acquires and transmits environmental data; the base station controls the remote station network and provides a data terminal compatible output. The overall system characteristics of the RAMOS base station and remote station will be discussed first, followed by more detailed design philosophy information. Much of the information in this section is taken directly from the RAMOS specification (reference 54).

1. Base Station Characteristics

The RAMOS base station is capable of controlling up to 25 remote stations, three modes for control of interrogation are provided. In the routine mode of operation a complete scan of remotes is performed at a switch selected rate of 4, 8, or 24 scans/day, or 2, 4, or 12 scans/hour. Interrogation times are referenced to a base station clock with a starting reference of 0000 hours. Switches permit operator initiated scans; a scan of all remote stations can be initiated by pressing a push-button switch. Any single remote station may be scanned by setting appropriate switches. The third mode is computer compatible; a computer originated command will initiate a complete scan of all remotes or the scan of any one remote. The base station/computer interface is compatible in code, format and language with typical minicomputers (NOVA 1200,DEC PDP-8).

Field stations will be designed to respond to a minimum of 750 interrogations/month. The limited power available at remote stations may cause a standby condition of power off; a delay of $\leq$ 3 minutes may be encountered from start of scan to beginning of output message.

2. Output

The basic output from the base station is an ASCII coded, bit parallel, serial by character data stream at 100 baud which is compatible with Model 33 Teletype-writers Ⓣ or their equivalent. Signal strength is sufficient to drive two machines each having 1000 feet of cable. The base station has provision for including a storage module to permit different output codes and data rates; one complete remote station message is stored.

The output message format is as follows:

OUTPUT MESSAGE FORMAT

B B B D D H H M M / REMOTE STA. MESS. / REMOTE MESS. / ... REMOTE MESS.

BASE STATION HEADER — REMOTE MESSAGES

BBB = Base Station ID 3 digits

DD = Calendar Date 00-31

HH = Hour 0-23 Local Time

MM = Minutes 00-50

REMOTE MESSAGE

R R S T T T / T_d T_d T_d / D D S S S / P P P S C C C S R S B

S = Space

RR = Remote Station ID 0-25

TTT = Temperature in ^{o}F; 1, 2, or 3 digits; -80 to +120^{o}F

$T_dT_dT_d$ = Dew Point in ^{o}F; 1, 2, or 3 digits; -30 to +86^{o}F

DD = Wind Direction in 10's of degrees; 2 digits always

SSS = Wind Speed in knots; min. of 2 digits, 3 above 99 KTS

PPP = Atmospheric pressure in hundredths of in. Hg. At least 3 significant digits

R = Yes/No precipitation; single digit 1 = Yes; 0 = No

B = Single digit number. Indicating remote on stand-by power

Error Handling:

A malfunction of a parameter may be indicated by replacing data with MMM. Remote station failure to respond is indicated by a field station I.D., no message.

Notice that minimal formatting is present; units are not printed, parameters are identified only by their order in the remote station message.

3. System Data Specification

The RAMOS parameter list is divided into two subsets; the basic (RAMOS I) set and a secondary set.

Basic Parameter List

1. Wind Direction
2. Wind Speed
3. Temperature
4. Dew Point
5. Surface Pressure
6. Cumulative Precipitation
7. Yes/No Precipitation

Secondary List

1. River Stage
2. Water Temperature
3. Tide Height
4. Wave Height
5. Radiation
6. Snow Depth
7. Min/Max Temperature
8. Evaporation
9. Soil Temperature
10. Dew Deposition
11. Soil Moisture
12. Prevailing Visibility
13. Cloud Height
14. Pollutant Concentration

The accuracy, operating range, sensitivity and reporting resolution for the primary parameter list is shown in Table 2. Overall system performance is specified from environmental parameter input to base station output.

Accuracy is defined as the root-mean-square error measured by multiple comparisons of RAMOS output values with true values; the true value being defined by real environment measurements using laboratory standards (high quality instruments in close proximity to RAMOS sensors) and measurements in precisely controlled environmental chambers. Each true value used in the RMS calculation is a 5 minute mean of the reading at a point in space. For total precipitation the true value is interpreted as the true total precipitation over a 5 minute period; the true value of yes/no precipitation measurement will be a yes if total precipitation over 10 minutes exceeds .01 inch.

Table 2. Output Data Quality for Basic Parameters (RAMOS)

PARAMETER	ACCURACY RMSE	OPERATING RANGE	SENSITIVITY	REPORTING RESOLUTION	ENVIRONMENTAL REGIME
Wind Direction	10 degrees	0 to 360 degrees	10 degrees	10 degrees	See Table 3, Column (1), Outdoor Environment for a list of the environmental extremes over which the performance specified in the preceding columns will be maintained.
Wind Speed	2 knots or 5%	0 to 125 knots	2 knots	1 knot	
Temperature	1.0°F ?*	-58° to + 120°F -80° to - 58°F	1°F	1°F	
Dew Point	1.5°F 2.5°F 3.5°F	+30° to + 86°F -10° to + 30°F -30° to - 10°F	1°F	1°F	
Surface Pressure	0.03 inches of H_g	3 inches Selectable from 19 to 31.5 inches of H_g	0.02 inches of H_g	0.01 inches of H_g	
Cumulative Precipitation	0.02 inches liquid	0 to 9.99 inches (reset on interrogation)	0.02 inches in less than 1 hour, liquid	0.01 inches	See Table 3, Column (1) except max. wind speed shall be 25 knots, and delete sand/dust laden atmosphere.
Yes/No Precipitation	9 correct in 10 trials	N/A	N/A	1 of 2 possible states	

*The ability to measure temperature between -80° and -58°F will be provided (as a modular add-on, if necessary); the accuracy cannot be specified at this time due to lack of data on cost/performance factors.

The operating range defines the range of values each parameters can assume; multiple ranges may be provided to accommodate multiple accuracy specification. Sensitivity is defined as the minimum amount of change in the true value of a parameter that must produce a RAMOS output change. Reporting resolution defines the value of the last significant digit in a parameter output value. Environmental Regime - Column 1 of Table 3 lists the environmental extremes over which the data quality specifications of Table 2 must be met; exceptions are:

sensors - cumulative precipitation/precipitation YES/NO

Wind speed $\leq$ 25 KTS; liquid precipitation only; atmosphere must be dust free.

Remote station electronics - Remote electronics package, transceiver package, power package operate only to -20^{o}F; burial of equipment or heating will be required under extreme conditions.

The remote station equipment must meet the requirements of Table 1 after exposure to the non-operating conditions of Table 2 column 3. All RAMOS equipment must be capable of operating under indoor environmental conditions as in Table 2 column 2.

4. Remote Station Characteristics

Sensors installed at the remote station location will interface with the environment to perform the initial data acquisition; the RAMOS remote station is designed to be able to accommodate up to 19 sensor inputs. It is understood that a one to one correspondence between parameters and sensors may not exist, as more than one sensor may be required to monitor a single parameter. One sensor plus extra conditioning may provide two parameter list outputs.

The remote station is designed to operate with either AC or DC Power Pack power sources; portions of the RAMOS are turned on upon command and turned off after interrogation is completed to conserve power. In the case of operation with a radio communication link, DC Power Packs sufficient for six months operation without servicing are used; a capability of 4500 interrogations at a rate not to exceed 750/month is provided.

Table 3. RAMOS Environmental Constraints

ENVIRONMENTAL CONDITION	OPERATING ENVIRONMENTAL LIMITS		NON-OPERATING ENVIRONMENTAL LIMITS (3)
	OUTDOOR ENVIRONMENT* (1)	INDOOR ENVIRONMENT (2)	
Temperature	-80°F to 130°F **	50°F to 122°F	-85°F to 149°F
Humidity	to 100% R.H.	to 96% R.H.	to 100% R.H.
Comb. Tem/Humidity	to 86°F at 100% R.H	to 86°F at 96% R.H.	to 149°F at 100% R.H
Altitude	to 10,000 FT.		to 14,000 FT.
Wind	2 to 125 KT	N/A	N/A
Rain	12"/Hr at 40 KT	N/A	4"/Hr
Salt Spray	Exposure to Salt Atmosphere	N/A	N/A
Dust/Sand	Exposure to Dust/Sand Laden Atmosphere	N/A	N/A
Sunshine	Exposure to Solar Radiation	N/A	N/A
Fungus	Exposure to Tropical Environment	N/A	N/A
EM Interference and Compatilibity	Exposure to Electromagnetic Environment Mil. Std. 461A Class IA and IB		N/A
Transportation Vibration	N/A	N/A	to 60 cps
Transit Drop	N/A	N/A	16" to 22" Drop
Bench Handling Without Shipping Container	N/A	N/A	4" Drop

* Icing--RAMOS components installed outdoors shall be capable of surviving icing conditions with up to 0.5 inch accretion. When iced, the equipment may not meet the performance requirements established in Section 3.0. However, the equipment shall return to normal operation upon removal of the ice.

** Electronics must be maintained at a temperature $\geq$ -20°F.

5. Communications Links

The RAMOS is designed to operate with land telephone lines, both private and dial-up, VHF radio transmission, and the Satellite Data Collection system. The communications interfaces are modular; one of 4 modules is selected for each remote station. The base station contains as many types of communications interfaces as are required by the remote station network. VHF transceivers are required for VHF radio transmission capability. The RAMOS remote station output will be compatible with Data Collection Platform Radio Set specifications; the satellite down link is to a Satellite Ground station and the function of receiving such data at the base station is not specified.

6. Maintenance Requirements

The design goal for the remote station is to obtain six month unattended operation; the required normal preventive maintenance, calibration, servicing and checkout or the repair of a malfunctioning station is to be accomplished by one electronics technician in a mean time of 2 hours. Test equipment and tools to accomplish this must either be built in to the remote station or be readily transportable and usable by a single man.

Base station maintenance, preventative or required by malfunction, also must be accomplished in a mean time of two hours by one electronic technician with the same constraints.

G. AMOSIII-70

The Automatic Meteorological Observing Station design was partially motivated by the need to reduce manual airport weather observations; the basic parameter list includes temperature, dewpoint, wind speed, wind direction, atmospheric pressure (altimeter setting), and accumulated precipitation. Add-on modules are being developed to monitor peak wind, visibility, the presence of clouds over the station, and yes/no precipitation. Switches permit the entry of certain manual observations. The station is designed to output information to the FAA teletypewriter network.

The station can accept up to 13 sensor conditioning cards; all sensor conditioning is to a digital output. The basic AMOS was designed to operate on AC power; the design operating environment is not hostile. A report on AMOSIII-70 is due sometime in April 1973.

H. SOUTHEASTERN FLORIDA FLOOD CONTROL PROJECT

The Southeastern Florida Flood Control Project will deploy an extensive system to gather hydrological and meteorological data from a large portion of the state. The object is to determine and control the ground water levels and to anticipate flood and water supply problems. A detailed specification is just being issued by the Army Corps of Engineers, but a limited description of the system can be given. Approximately 16,000 sensors will be involved, including very accurate water level sensors. A full double loop microwave radio link will form the backbone of the communications network. A fifteen mile repeater separation is expected, and special processing stations interface between the microwave network and the remote stations. Remote power is supplied by storage batteries with solar recharging units.

I. COMMERCIAL EQUIPMENT PRESENTLY AVAILABLE

In this section will be discussed a few representative hydrological/meteorological remote data acquisition equipments, apparently applicable to the proposed network. Individual environmental sensors and instruments, as well as communication equipments, have been omitted. A wide spectrum of manufacturers of such devices exists, making such a survey beyond the scope of this report.

1. Seismograph Corporation

Seismograph Service Corporation, Seiscor Division makes a data gathering system, called Vericom, which allows a central station to interrogate or poll up to one thousand remote stations. The common carrier equipment is not included but a low grade voice channel is assumed. The equipment supplied includes N-level frequency shift keying and permits operation with a poor signal to noise ratio. Noise monitor and error detection circuits are included.

2. Metrodata Systems

Metrodata Systems, Inc., a subsidiary of Weather Science, Inc., manufactures a data acquisition system intended for use in the collection of remote weather parameters. The remote station can handle eight or sixteen channels and converts analog data to digital form for transmission via a suitable telemetry link. The master station can serve up to 20 remotes in either a polling or automatic self-timed mode. Options include automatic battery back-up power, five different remote commands, and compatible interface with teletype, display, printer, or computer equipment.

3. Computing Devices of Canada

Computing Devices of Canada Limited, a subsidiary of Control Data Corporation, manufactures an automatic data acquisition system, designated the PHI-tran system, which consists of a master and remote stations. The remote station can accept both digital and analog inputs from up to 12 sensors and provides for serial transmission in BCD form. The design allows operation over the temperature range $32^{o}F$ to $120^{o}F$. The master station includes a data time clock, printer output, and error detection, and handles up to 10 remote stations. The system was developed jointly with the Canadian Forest Fire Research Institute.

4. Thiokol Corporation

The Astronet Division of Thiokol Corporation produces a hydrological telemetry system (HY-TEL). The remote station is of modular design and is capable of accepting digital and analog sensor inputs; one card is added for each digital sensor. Analog inputs are multiplexed; 8 inputs are added for each additional multiplexer card. The station message is character oriented with a maximum length of 99 characters; transmission is in ASCII code. Parity and redundancy are used for error control. The logic is MIL spec; the unit is specified over -30 to $+60^{o}C$ operating range. The base station contains a NOVA 1220 minicomputer, the amount of memory determines the number of remotes accommodated by a base station; 16K of memory accommodates 100 stations. Each 8K memory increment permits adding 100 more remote stations. The base station output can interface a teletype machine or higher order system.

PART II NATIONAL FIRE DANGER MONITORING SYSTEM

A. OVERALL SYSTEM DESCRIPTION

The automated implementation of the National Fire Danger Monitoring System will require the automation of each of three phases of the system; the system contains requirements for data acquisition, computation and storage, and output data distribution. The input data set is comprised of remotely sensed parameters which could originate from automated or manual observations at remote isolated stations. Sources for this data could include Forest Service and non-Forest Service remote station networks.

The computing/storage function is assumed to be operated under Forest Service authority with data input to be accepted from Forest Service Networks and non-Forest Service networks. Computing function output would include real-time data for Fire Control utilization and secondary output for Forest Service and inter-agency users.

High priority data output distribution would satisfy requirements for distribution of real time computed output to data source locations and perhaps to regional fire control personnel. Additionally, output of Forest Service data to interested users would be required; computed output would be distributed to interested users including Forests adjacent to the data source within or external to a region. Lower priority outputs could require distribution of statistical information and maintenance summaries.

Overall system data flow is depicted in Figure 1; emphasis will be placed on the functional requirements for automated data acquisition. The implications of the requirements for real time data acquisition using mixed networks will be discussed.

B. REMOTE STATION NETWORK

The function of the remote station network is to monitor environmental parameters at remote station locations and convert these parameters into an output compatible

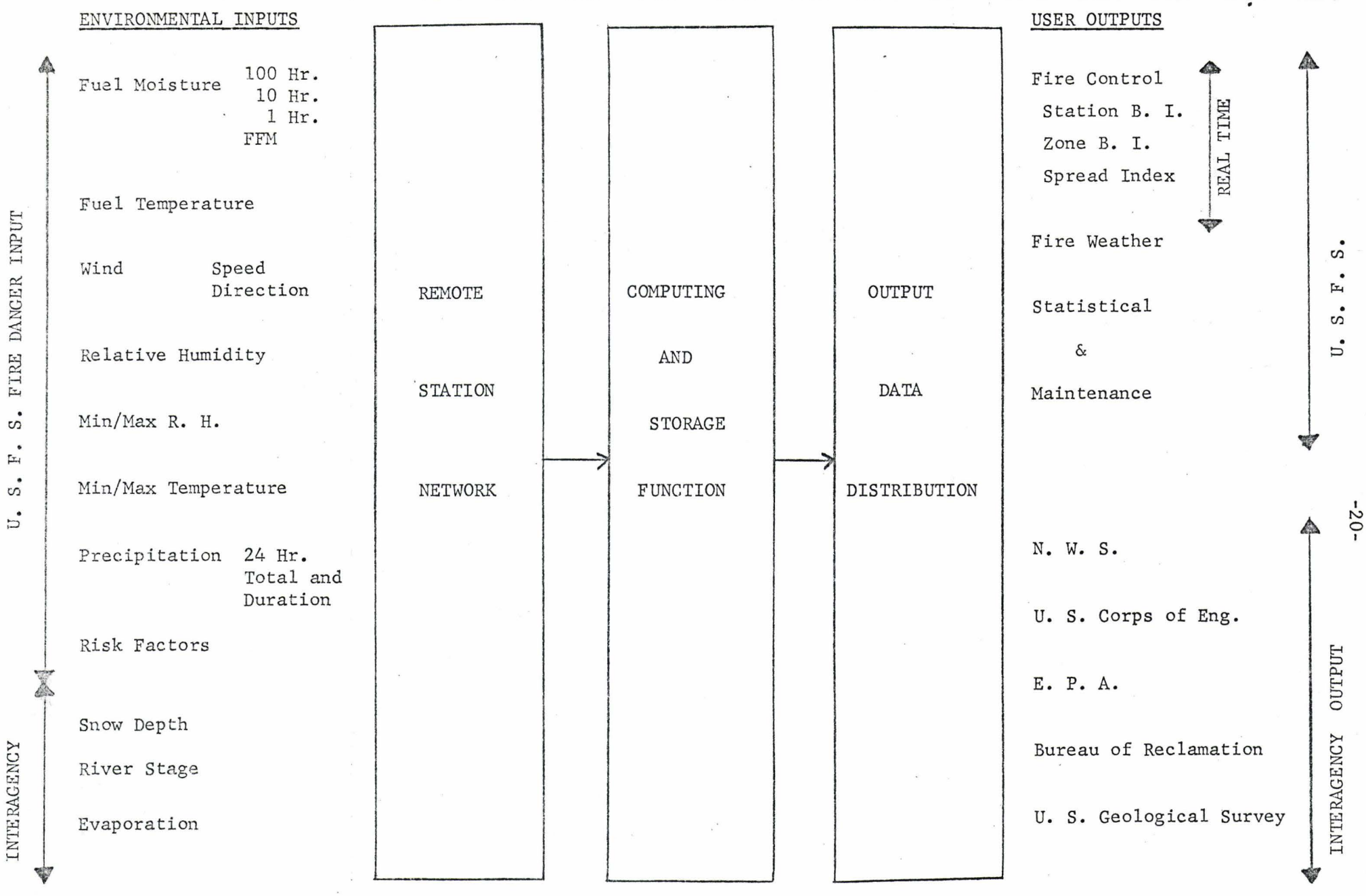


Figure 1. Automated Fire Danger Rating System Data Flow

with the data processing system. Physically, the function would be realized with Forest Service operated networks, and with networks operated by other agencies.

Figure 2 shows the remote station network in more detail. Three functional elements are present: (1) the remote stations (automatic or manual) at which environmental parameters are monitored and prepared for transmission, (2) the telemetry link which provides a means for transmitting data to/from remote station locations, and (3) the remote collection center which receives data from multiple remote stations and converts this data into a form compatible with data equipment.

In this general example, the output from a remote collection center would be a mixture of flammability, fire weather, and non-fire danger rating sensor readings from several remote stations. The remote collection centers could be within either Forest Service or non-Forest Service networks. It seems realistic to assume that a mixed remote station network will exist for some time. That is, manual data entry and automated remote data entry will exist concurrently. Even if most remote station data is automatically acquired, some need exists for manual entry of lightning and man-caused risk, for example. Consideration should then be given to designing the Remote Collection Center equipments to be compatible with both automated and manual entry requirements. Further considerations may be required to integrate the Remote Collection Center data transmission and processing function with general computer user requirements.

1. Automated Remote Station Network Design Goals

The automated remote station network is implemented to gather flammability, fire weather, and other hydrometeorological data from isolated areas. Deployment of remote stations in areas with difficult access will lead to the following design goals.

a. Reliability. Lack of access, an infrequent maintenance schedule, and a need for reliable, accurate data transmission under harsh environmental conditions require a design philosophy with emphasis on reliability for all remote station components.

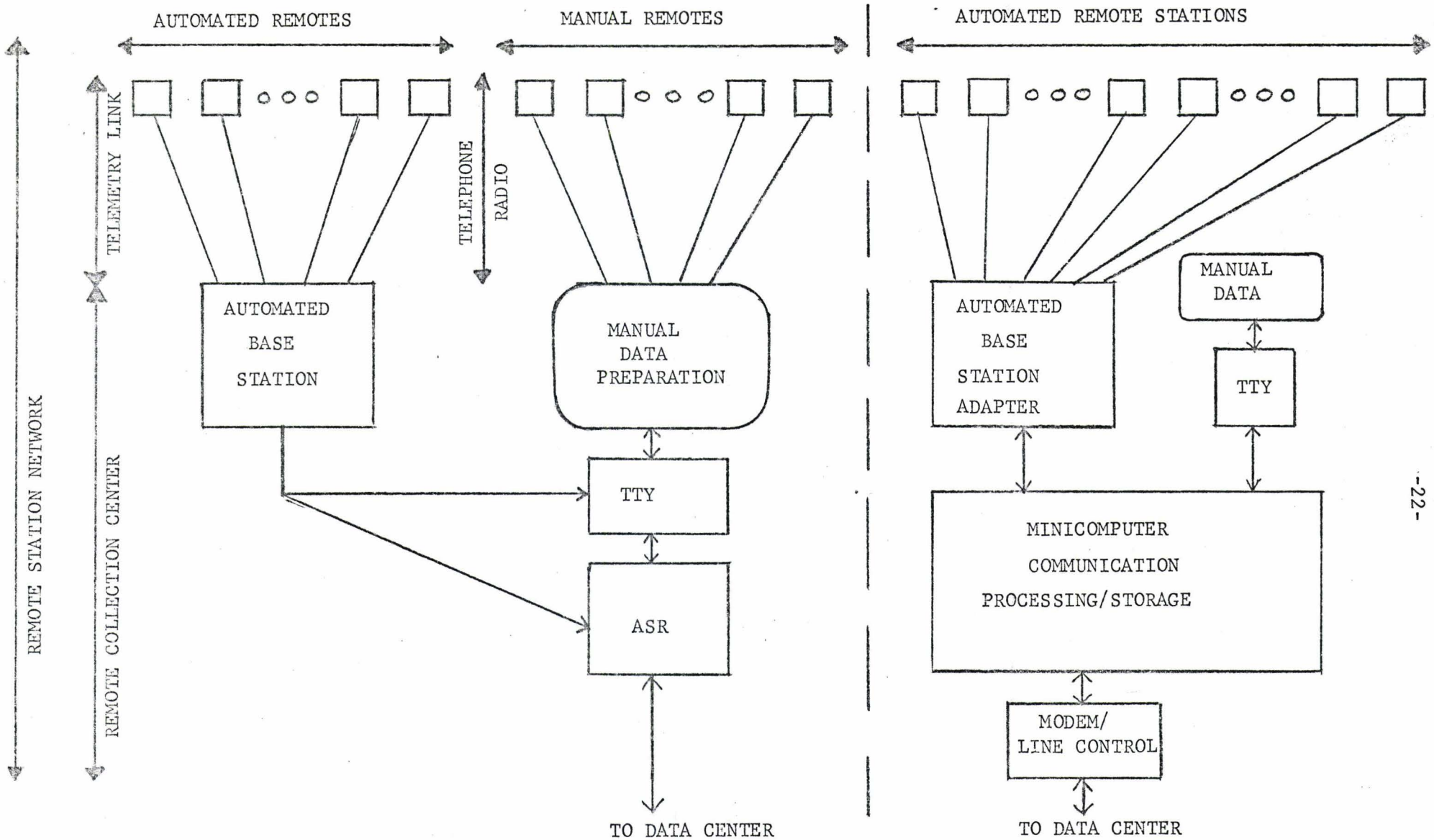


Figure 2. Remote Station Network

b. Maintenance. Remote station maintenance would be performed in the field. Minimal test equipment should be required to perform all required maintenance, troubleshooting, and repair. A design approach resulting in a unit containing plug-in circuitry and functional modules will minimize maintenance time.

c. Power requirements. Remote deployment will likely result in operation from storage battery sources. To maximize operating time the remote station should be designed with low power circuits and sensors. A standby mode of operation with power applied to only a portion of the station will extend the operating period.

d. Portability. The size and weight of remote station components should be specified to permit installation by perhaps two men.

e. Flexibility. The need to operate with a variety of communications links suggests plug-in modules for communications interfacing; the need to accommodate different types and numbers of sensors further suggests a modular construction.

f. Economy. Design of the remote station should minimize cost within the limits imposed by reliability and accuracy requirements. Minimizing the cost per remote station over an operating period should be the goal.

2. Automated Remote Station Network Functional Design

a. The network will consist of three types of subsystems: a remote station subsystem, a remote collection center (base) station subsystem, and a communications network interconnecting the base station and its associated remotes.

b. The communications links available will typically be voice-bandwidth; link types include UHF/VHF radio systems, microwave systems, and telephone lines. The communication links may be shared with other users. Satellite communications will require special adapters in the form of a Data Collection Platform at the remote site, and a Satellite Ground Station for the down-link from the satellite.

c. The flammability station will monitor a minimum of 6 input parameters; the flammability/fire weather station will monitor a minimum of 13 parameters.

d. The smallest unit of the Automated Remote Station Network will consist of one base station subsystem, several remote station subsystems, and the communications subsystem.

e. The base station output will provide the required environmental information in a terminal oriented code; computation and storage in Government facilities requires ASCII coding. The output would be used to interface a minicomputer, a tape punch, or a teletype unit.

f. The base station will control the scanning of the remote stations and this cycle could be programmed within the base station. Provisions for manual control and control by a minicomputer is desirable.

g. The base station would operate on commercial AC power of 105-130 volts. The remote stations should be capable of using this source although battery operation will usually be required.

3. System Data Quality

One of the first steps required in the system design of the remote station network is a definition of the environmental parameters to be monitored by a remote station. A primary parameter list would presumably consist of the Flammability/ Fire Weather station parameters. A secondary parameter list also should be drawn up, listing the parameters which would be required to supply data to interagency users.

PRIMARY PARAMETERS

Flammability Station

Fuel Moisture (1-4)

1. FFM
2. 1 hr. T.L.
3. 10 Hr. T.L.
4. 100 Hr. T.L.
5. Fuel Temperature
6. Wind Speed (1 Hr. run)

Flammability/Fire Weather

Fuel Moisture (1-4)

5. Fuel Temperature
6. Wind Speed (1 Hr. run)
7. Wind Direction
8. Air Temperature
9. Atmospheric Moisture
10. Max./Min. Temperature
11. Max./Min. Relative Humidity
12. 24 Hr. Precipitation Duration
13. 24 Hr. Precipitation Accumulation

SECONDARY PARAMETERS

Hydrological/Meteorological Parameters for Interagency Use

1. River Stage
2. Water Temperature
3. Tide Height
4. Wave Height
5. Radiation
6. Snow Depth
7. Evaporation
8. Soil Temperature
9. Dew Deposition
10. Soil Moisture
11. Visibility
12. Cloud Height
13. Pollutant Concentration

The system data quality requirements should then be established for the primary parameters. Accuracy, range, sensitivity, and resolution for the entire system would be specified in this step. In preparing this specification, the method for evaluating accuracy would be defined for each parameter; the precise definition of these requirements would permit a realistic evaluation of the compatibility of existing systems with design data quality goals.

Table 4 shows the initial data quality requirements for fire weather and flammability and allows a comparison with those specified for RAMOS. The reporting ranges required are compatible with data systems providing three digit data representation, with the exception of 24 hour precipitation accumulation and 24 hour precipitation duration (true readout in minutes). This conflict could be resolved with interrogations four times per day with processor computation of 24 hours totals.

The requirement for accuracy implies the existence of secure, error-controlled communication of data between the remote station and the computing center. It is expected that the VHF radio communications link between the remote station and the base station will typically experience burst errors due to interference, lightning, and multipath reception. Real time data acquisition requires the automatic detection of such errors and corrective action. Input software at the computing center could identify and correct errors if sufficient initial data encoding is used. Corrective action could include substitution of averaged data from adjacent stations, substitution of archival data, or issuance of a command to reinterrogate the remote station. Forward error correction techniques could also be implemented.

Table 4. Data Quality Requirements on Fire Weather and Flammability Parameters

PARAMETER	ACCURACY (RMSE)	OPERATING RANGE	SENSITIVITY	REPORTING RESOLUTION	ENV. REG.
Fuel Moisture	.1% Moisture Content	00.0 -> 30.0%		≤.1% Moisture Content	
Fuel Temperature	1°F	20 - 140°F		1°F	
Wind Speed (1 Hr.)	---	0 -> 100 MPH		1 MPH	
(RAMOS)	(2 Knots/5%)	(0 -> 125 Knots)	(2 Knots)	(1 Knot)	
Wind Direction	---	0 -> 7 pts		45°	
(RAMOS)	(10°)	(0 -> 360°)	(10°)	(10°)	
Air Temperature	1°F	(-58°F -> +120°F)	(1°F)	(1°F)	
24 Hour Precipitation	.01 inch	0.00 -> 24.00		.01 inch	
Total (RAMOS)	(.02 inches liq)	(0.00-> 9.99 in) Reset on Int.	(.01 in. liq in less than 1 hr.)	(.01 inch)	
24 Hour Precipitation Duration	5 min.	0-288 5 min Int. or 0-1440 min		5 min. 1 min.	
24 Hour Min/Max Temp. (On RAMOS Secondary Parameter List)	1°F/1°F (?)	20/20-130/130(?)		1°F/1°F (?)	
Relative Humidity (Dew Point)	--- (1.5°F) (2.5°F)	0-100% (+30° -> +86°F) (-10° -> +30°F)	1°F	1% 1°F	
24 Hour Min/Max R.H.		0/0--100/100(?)		1/1 (?)	

RAMOS Specifications Entered as (XXX)

The requirement for data quality also leads to consideration of the methods to detect the failure of a sensor, for example, and the means of replacing this data previous to computation. Once again, software functions could perform checks to determine the compatibility of the data with previous readings or averaged readings among adjacent stations. Corrective action could consist of replacement with averaged or archival data, or data from redundant stations.

C. REMOTE STATION SUBSYSTEM

The remote station subsystem performs the function of interfacing with the environment, monitoring selected environmental parameters, and transmitting these parameters to the remote collection center base station equipment. The remote site equipment necessary to accomplish this task is outlined in Figure 3. The equipment would include sensors, a remote electronics unit, a power source, communications equipment, and enclosures for environmental shielding.

1. Sensors

The sensors provide the point of interaction between the environment and the data acquisition system. Actual sensor selection must be governed by compatibility with system requirements regarding environmental operating range, accuracy, resolution, output characteristics, power consumption, reliability, and maintenance. The installation of the sensors will influence the accuracy of the system; suitable physical supports must be specified and provided.

Each entry in the parameter list will be translated into sensor equipment requirements; alternative sensors would be investigated. In general, the monitoring of an environmental parameter may require one or more sensors. In some instances, only additional sensor conditioning electronics may be required to provide data for several parameters from one sensor.

The basic parameter list for the flammability station suggests that only one sensor would be required for each of the parameters; that is, one fuel moisture analog would be used for each of the fuel moisture entries, while fuel temperature and

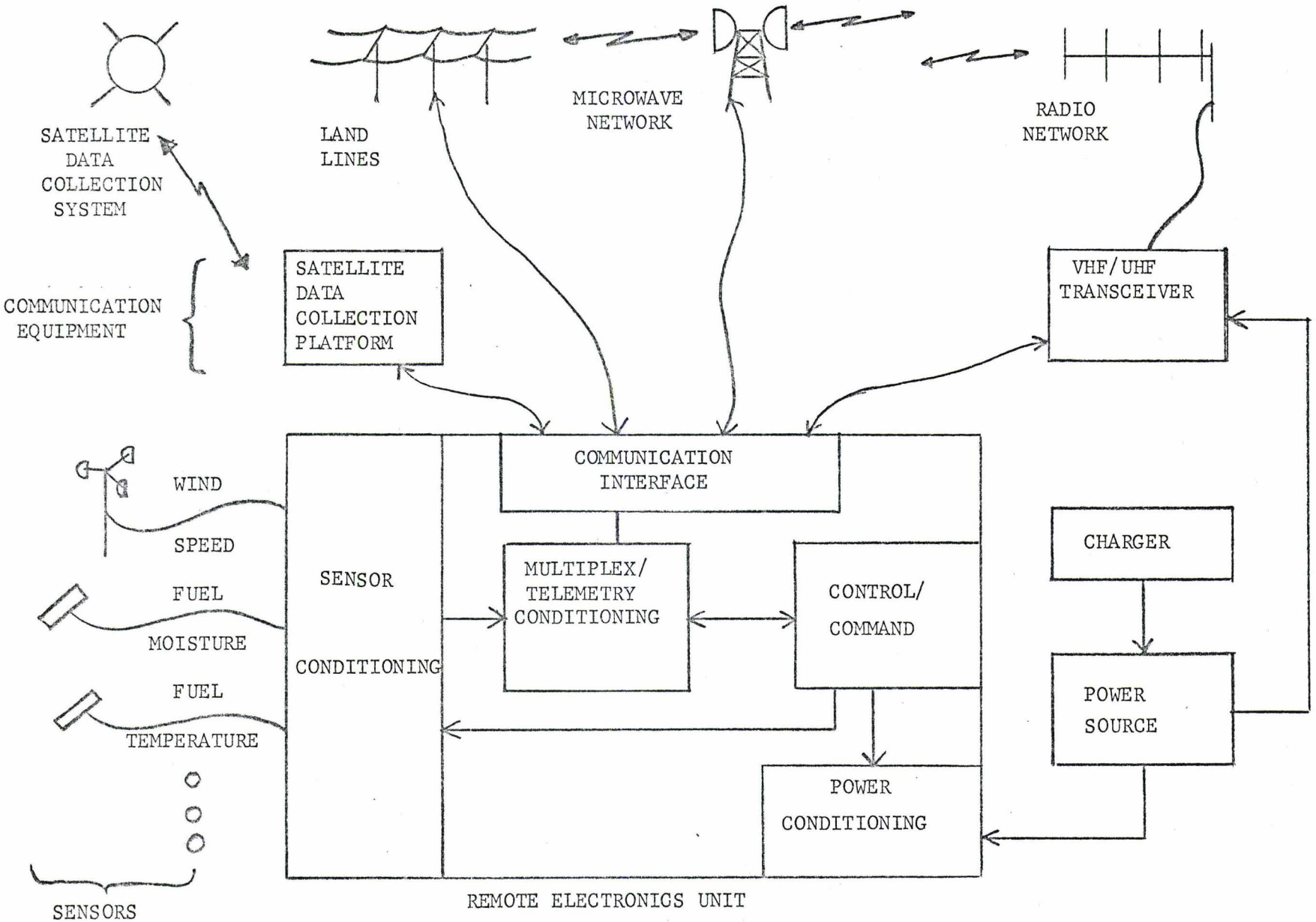


Figure 3. Remote Station Subsystem

wind speed would each also require one sensor. The Flammability/Fire Weather station parameter list includes entries that could require data from more than one sensor. Determination of atmospheric moisture could be by measurement of wet bulb and dry bulb temperatures, determination of dew point and air temperature, or direct determination by means of an hygrometer or humidity sensing element. The air temperature reading could be provided by the air temperature sensor.

Max/min temperature readings could be acquired either by means of a specialized sensor, or by additional conditioning including the sampling of the temperature sensor data and updating the min/max stores. Precipitation accumulation could presumably be monitored by a tipping bucket sensor; precipitation duration could be derived from this sensor by determining the number of time periods that the rate of accumulation exceeded the required sensitivity level. The method would not provide the required 5 minute resolution of duration. An alternative would be to sample a fast reacting yes/no precipitation sensor and accumulate the time periods of detected precipitation. Determination of 24 hour min/max relative humidity would require either a specialized sensor or conditioning of a relative humidity sensor in a manner similar to the min/max temperature conditioning.

In general, sensor outputs will be either analog or digital in nature; the analog output being of a continuous nature, the digital output being of a discrete nature. Examples of analog variables would include voltage from a wind speed sensor generator, resistance from a shaft position indicating potentiometer or from a temperature sensing thermistor, capacitance from a dew point sensor, and inductance from a transducer indicating linear or rotary position. Digital variables could be in the form of the pulse rate from a mechanical switch or photo chopper in a wind speed sensor, or from a tipping bucket precipitation accumulation sensor, or from certain "Digitized" instruments (Towner, Berkeley), or digital words from a digital shaft encoder.

The telemetry encoding method selected should be compatible with sensors providing either analog or digital outputs. The remote electronics unit will further be required to condition power for the sensors, provide timing/control signals to the sensors, and perform required sensor conditioning. Output from the system

study would be a list of sensors fulfilling the requirements outlined. Reliability, maintenance requirements, power requirements, physical support requirements, cost, and control requirements would be outlined for each sensor to permit the definition of system reliability, system maintenance, system cost, system weight, system power and system control requirements. Sensor accuracy, resolution, and range of operation could be defined either in terms of system requirements or for the sensor proper.

PARAMETER LIST		SENSOR SET	
Parameter Resolution		Sensor Types	Output Types
Accuracy	LEADS TO →	Resolution	Output Ranges
Range		Accuracy	
Reliability		Range	
Type of Reading		Reliability	
(i.e., peak, min/max average period, etc.)		Cost	
		Weight	
		Cabling	

2. Remote Electronics Unit

The function of the remote electronics unit is to interface with the various environmental sensors, condition the sensor output, encode the sensor data for transmission, control the transfer of data to and from the communications link, condition the power available from the primary power source, and provide the control and timing signals that are required at the remote station location. The overall system function, then, is to interface with the environmental sensors and transmit this data to the communications subsystem.

Figure 3 shows the functional elements required within the remote electronics unit. Alternative implementations of this function are possible; regardless of implementation, however, the functions of sensor conditioning, power conditioning, control/command implementation, polling implementation, error control, and, to a certain extent, communication interface will be essentially constant. These items are discussed separately later.

The approach taken in discussing some alternatives is to refer to the functional description of the remote station network. The design goal is to telemeter remotely sensed environmental parameters and derive a data system compatible output. The final digital nature of the output requires that conversion to a digital format be performed at some point within the system. The point at which digital conversion occurs is a variable and the means of multiplexing sensor data is also a variable.

In discussing the alternatives, communications bandwidth will be assumed as voice grade and time sharing with other users will be assumed. Further, the communications link will likely be by radio. Error control encoding techniques will be mentioned, as will be compatibility with a Satellite Data Collection System. Limits regarding the number of sensors accommodated will also be discussed.

Regarding the transfer of data from multiple sensors at a remote station site, either time division multiplexing or frequency division multiplexing of the communication link can be utilized. FDM will be presumed to communicate both analog and digital variables. TDM could use either digital data encoding or analog data encoding for remote to base communication and these cases will be discussed separately.

a. Power Conditioning

The power conditioning function accepts raw unregulated power from a primary power source and conditions this power for use by the sensors and the remote electronics unit. Functions performed could include: (1) conversion of one source voltage to the several different levels required by logic circuits, analog circuits, and sensors, (2) regulation of voltage levels to permit circuit operation with specified accuracy, (3) control of distribution since certain equipments could require continuous power, while other equipment might require power only during interrogation periods or at other intermittent times during the day, and (4) protection of equipment against over-voltages and transients on the primary power source.

b. Frequency Division Multiplexed Telemetry

Figure 4 shows the remote electronics unit functional block diagram required to implement a frequency-division-multiplexed telemetry encoder. One subcarrier oscillator is used for each sensor. The subcarrier oscillators operate within separate segments of the available frequency spectrum. Frequency modulation of the subcarriers will be assumed; either digital or linear (analog) modulation could be used.

With digital modulation the subcarrier oscillator will be frequency-shift-keyed by the pulse train output of the sensor conditioning electronics. Sensors and conditioning leading to pulse rate or pulse width modulated streams, or serial data streams could be accommodated. With linear modulation, the deviation in frequency of the subcarrier would become proportional to an analog variable. Two types of oscillators are possible, a voltage controlled subcarrier oscillator and a variable inductance/capacitance controlled oscillator. The VCO would be driven by sensors conditioned to a normalized output voltage range while the second type would be directly modulated by some transducers. The set of subcarriers would be combined and transmitted over the communications channel; this set could consist of a mixture of the oscillator types mentioned.

Figure 5 shows the base electronics unit required in the FDM telemetry system; a filter bank splits the communication link output into a set of channels of different segments of the frequency spectrum. For each channel a demodulator is required; the same type of demodulator (a frequency to voltage converter) can be used for all channels.

The procedure from this point on in the system will depend on the modulation used within a channel. Channels which were linearly modulated would be multiplexed into an A/D converter to obtain a digital output. Channels which were pulse-width modulated could be integrated and passed through the A/D. Channels initially pulse rate modulated would require conversion to a digital format. Channels modulated with a serial data stream would be staticized. Outputs from all different channels would be organized into a time sequential message format with required headings and code conversions would be performed.

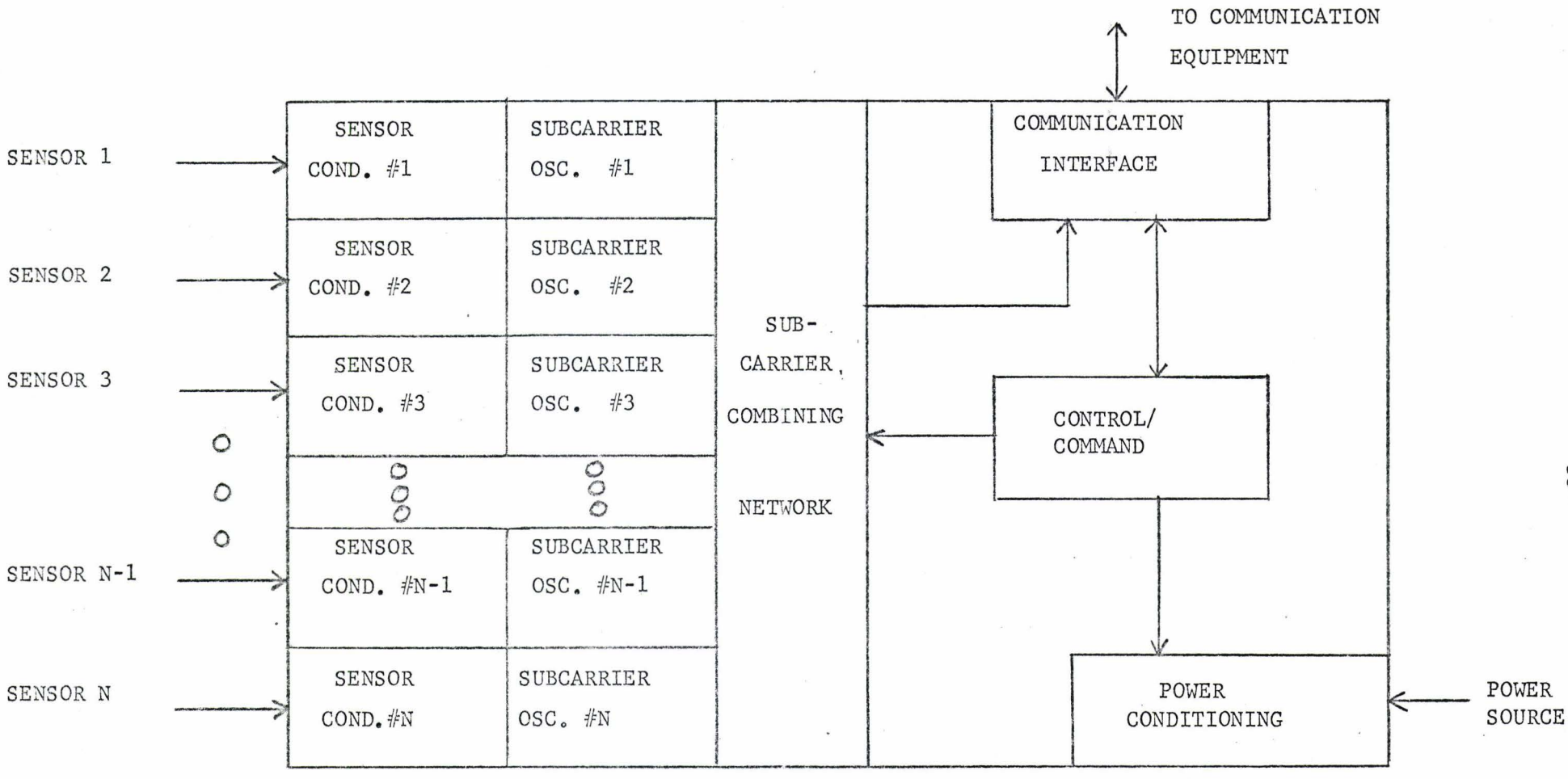


Figure 4. Remote Electronics Unit - FDM

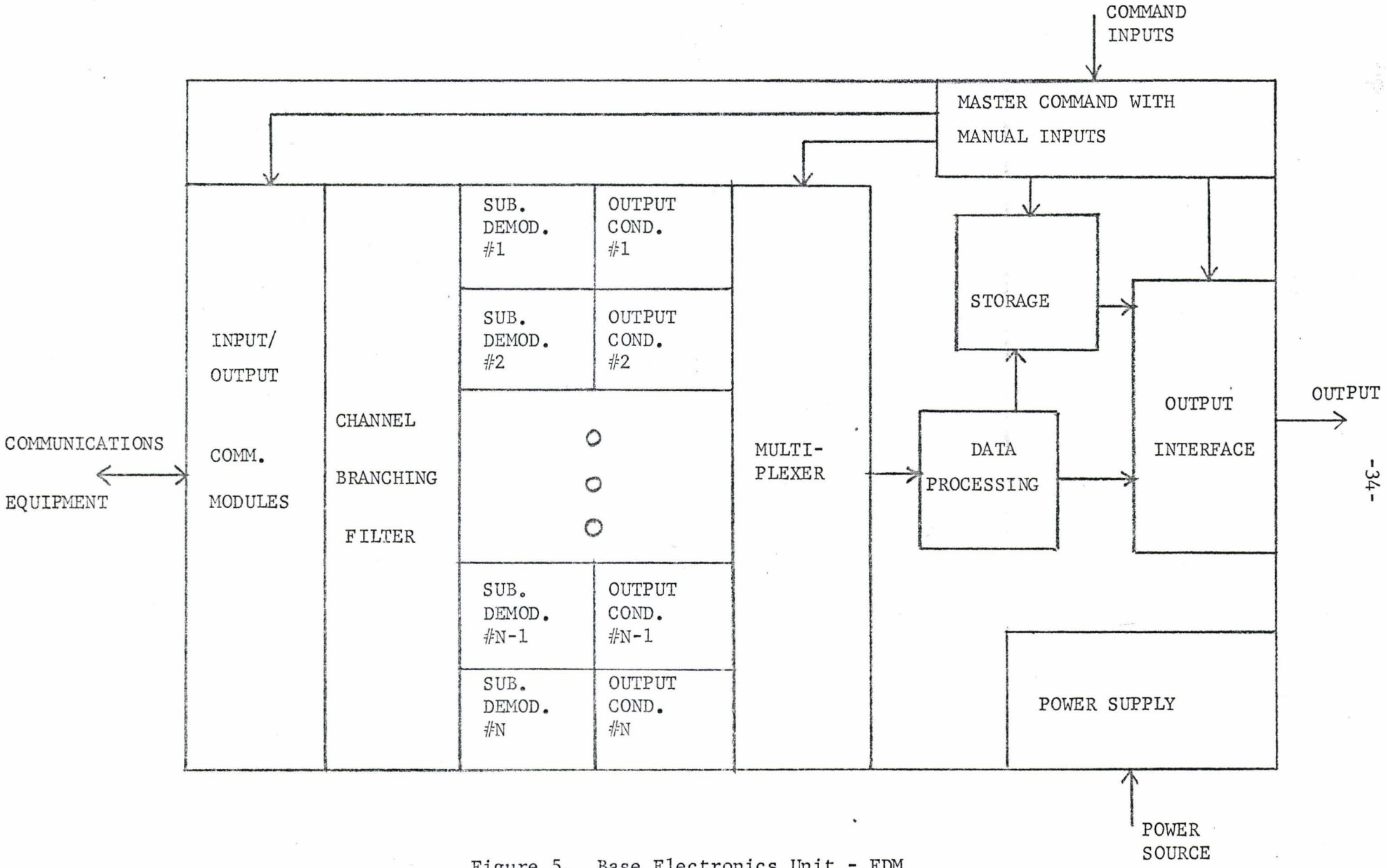


Figure 5. Base Electronics Unit - FDM

The general characteristics of frequency division multiplexing can be summarized as follows.

1) System complexity and cost are nearly proportional to the number of sensors used; functions are duplicated for each channel from the input of the remote electronics unit through much of the base electronics unit.
2) To maintain accuracy each subcarrier oscillator and demodulator must be carefully adjusted and compensated against temperature and supply voltage variation.
3) The system is affected by transmission system frequency offset (except the serial data channels).
4) The multicarrier nature of the signal will force a reduced subcarrier level compared to single-tone transmission; 13 channels would cause an eleven (11) dB level reduction.
5) The implementation may be incompatible with the Satellite Data Collection System; conversion to a digital format occurs at the Remote Collection Center.
6) A separate subcarrier would be required for remote I.D. transmission.
7) Remote station control requirements during interrogation are minimal, as data is transmitted simultaneously.
8) Remote station types cannot be readily mixed, unless identical encoding is used for all sensor data channels.

c. Time Division Multiplexed Telemetry/Analog Transmission

One form of TDM telemetry encoding is shown in Figure 6; sensor conditioning electronics would convert sensor inputs to an analog output voltage variable. The conditioned outputs would be time sequentially sampled by an analog multiplexer while additional multiplexer inputs could be used to transmit calibration information. The multiplexer output would modulate the frequency of a voltage controlled oscillator. This oscillator output would be connected to the communications interface and the output, after level setting, would be compatible with voice bandwidth transmission systems. Synchronization can be provided by transmitting a precise number of cycles of carrier for each sensor data point required; remote station I.D. information could be transmitted by digitally keying this carrier, or by including a separate subcarrier for I.D. transmission.

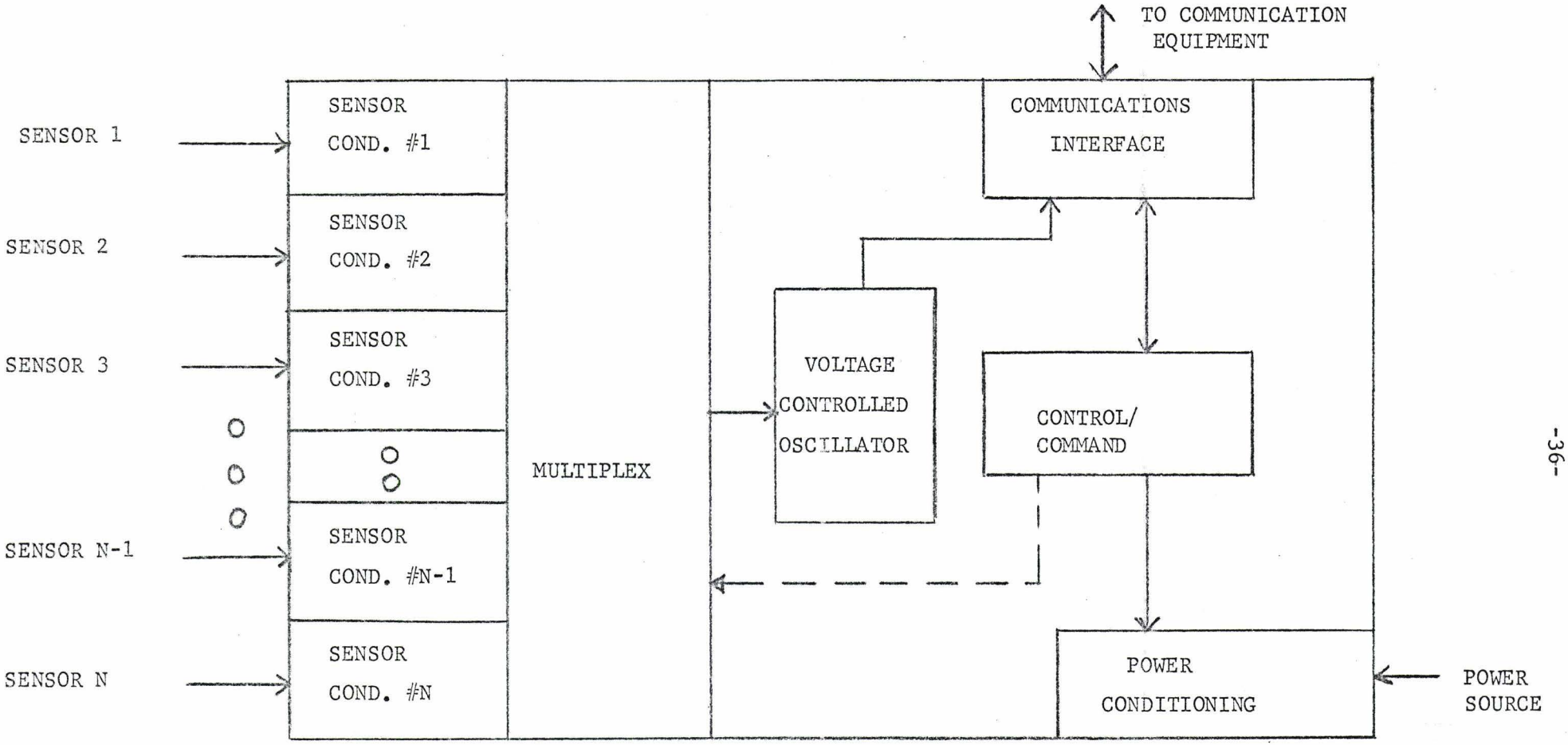


Figure 6. Remote Electronics Unit - TDM/Analog Transmission

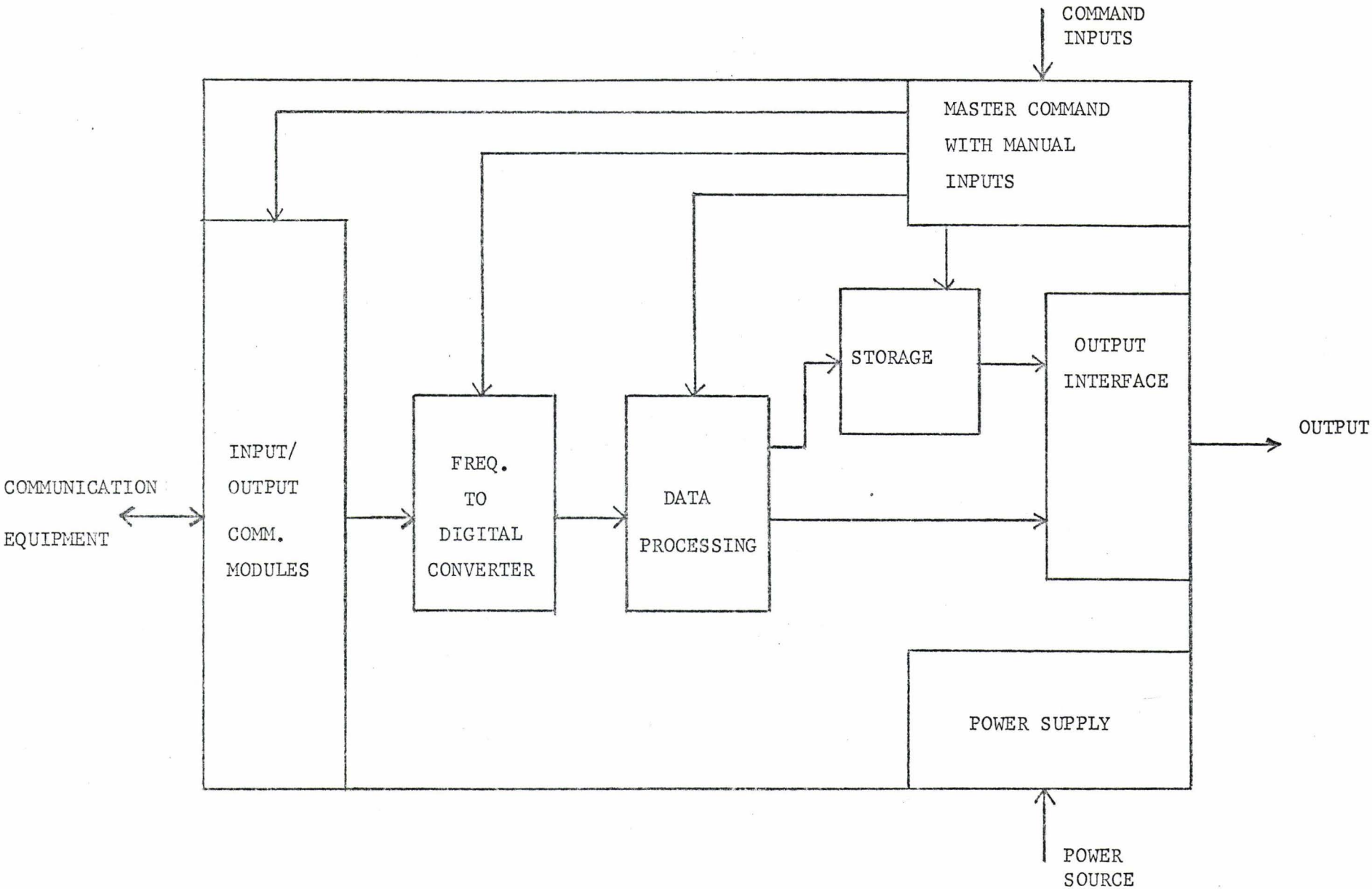


Figure 7. Base Electronics Unit - TDM/Analog Transmission

The base station unit is shown in Figure 7; the received oscillator frequency would be converted to a digital output. This could be accomplished by directly converting the received frequency to a digital representation; or could be implemented by performing an intermediate conversion of frequency to voltage, and a final voltage to digital representation conversion. Initially encoded synchronizing information would provide control for the assembly of the serial output message (see reference 50 in the bibliography).

TDM/analog transmission characteristics can be summarized as follows:

1) Sensor conditioning providing an analog voltage output is required; sensors providing a digital output will require conversion to this form.
2) Conversion to digital form does not occur at the Remote Station; this may have implications regarding Satellite Data Collection System compatibility.
3) Short term phase/frequency variations in the communications subsystem will affect accuracy.
4) Analog transmission could increase susceptibility to interference; link signal to noise requirements will be greater than for digital data encoding.
5) Detection of errors induced by burst noise conditions would be difficult.
6) Oscillator operating frequency and range would need to be adjusted to be compatible with other than voice grade communications.
7) The approach shows some promise of being economical if equipment is available and extensive development is not required.

d. Time Division Multiplexed Telemetry/Digital Transmission

The functional diagram for the remote electronics unit is shown in Figure 8; sensors most readily conditioned to a normalized output voltage range will be sequentially scanned by an analog multiplexer and converted to a digital word by an A/D converter. Sensors and conditioning resulting in digital output words would be multiplexed with the A/D converter output using a digital multiplexer or digital bussing techniques.

The telemetry processor could reformat the data, add data error encoding check bits, and add the control bits required for transmission. The communications interface would encode the data stream for transmission over the voice-bandwidth link (FSK modem function).

The base station electronics unit is shown in Figure 9; the data processor input would be the serial data stream corresponding to the remote station telemetry processor output. Data processing functions could include code conversion, conversion to engineering units, etc. The storage function would permit different base input/output data rates or code types. For example, remote/base communications could be asynchronous and character oriented; high speed transmission from the base to a computing facility could require a conversion to a packed, synchronous data block. A remote station message would be stored to permit this conversion. The output module would convert the processor or storage module output to be compatible with the desired system output.

The characteristics of TDM/Digital Transmission can be summarized as follows:

1) Sensors which can be conditioned to result in either an output voltage representing sensor data or to a digital output representing sensor data can be accommodated.
2) Error control encoding can be added to the station data message.
3) The station data rate can be adjusted to aid performance under noisy communication link conditions.
4) The remote station I.D., headers, spacing characters, and sensor type identification can be added to the basic data message.
5) The digital mode of transmission is insensitive to network frequency offset.
6) All sensor data is available in digital form at the remote station; conversion for satellite network collection should be feasible.
7) The remote station data path is through one set of functional elements; engineering this one path for reliable operation guarantees transmission of some good sensor data.

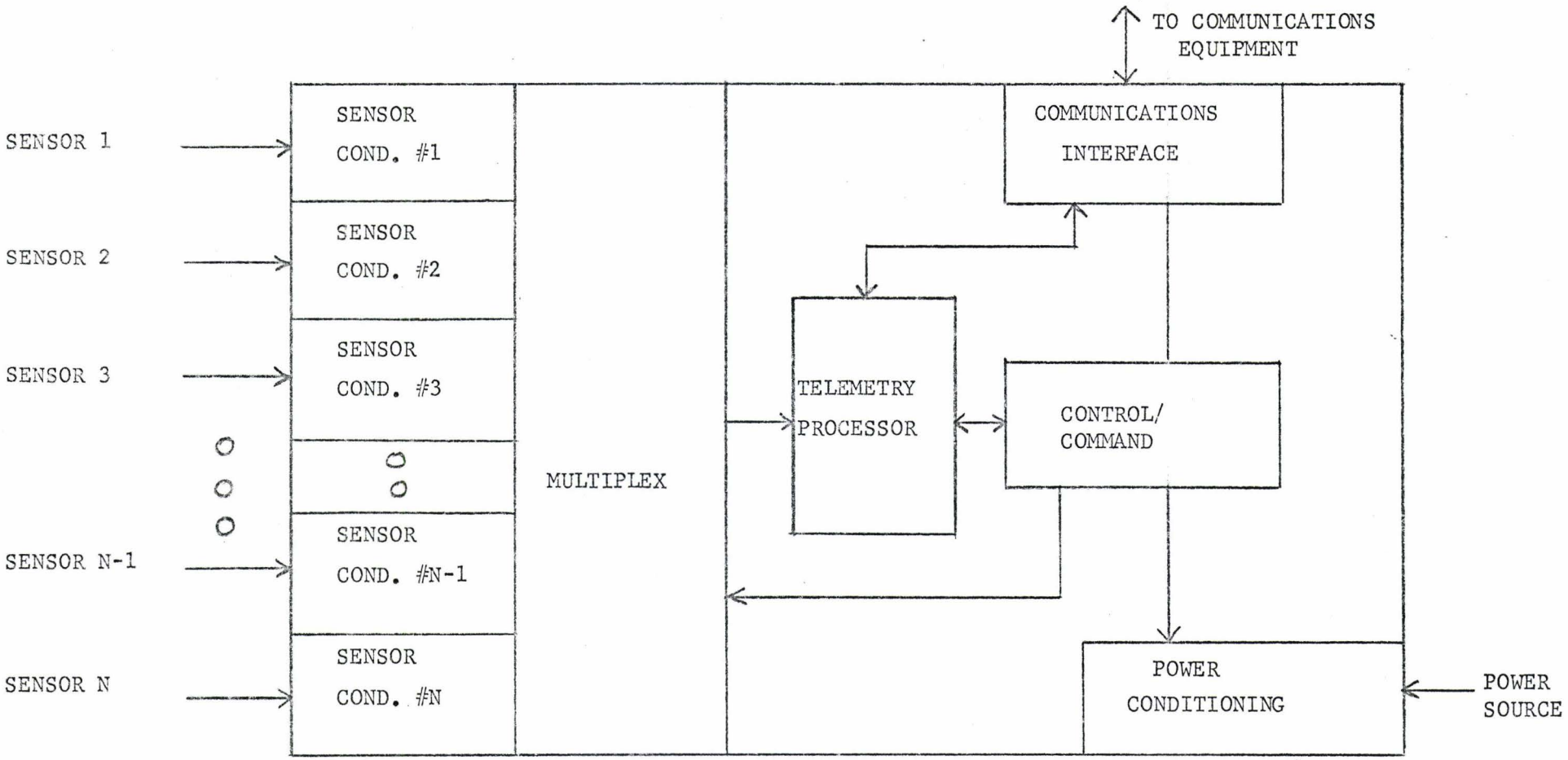


Figure 8. Remote Electronics Unit - TDM/Digital Transmission

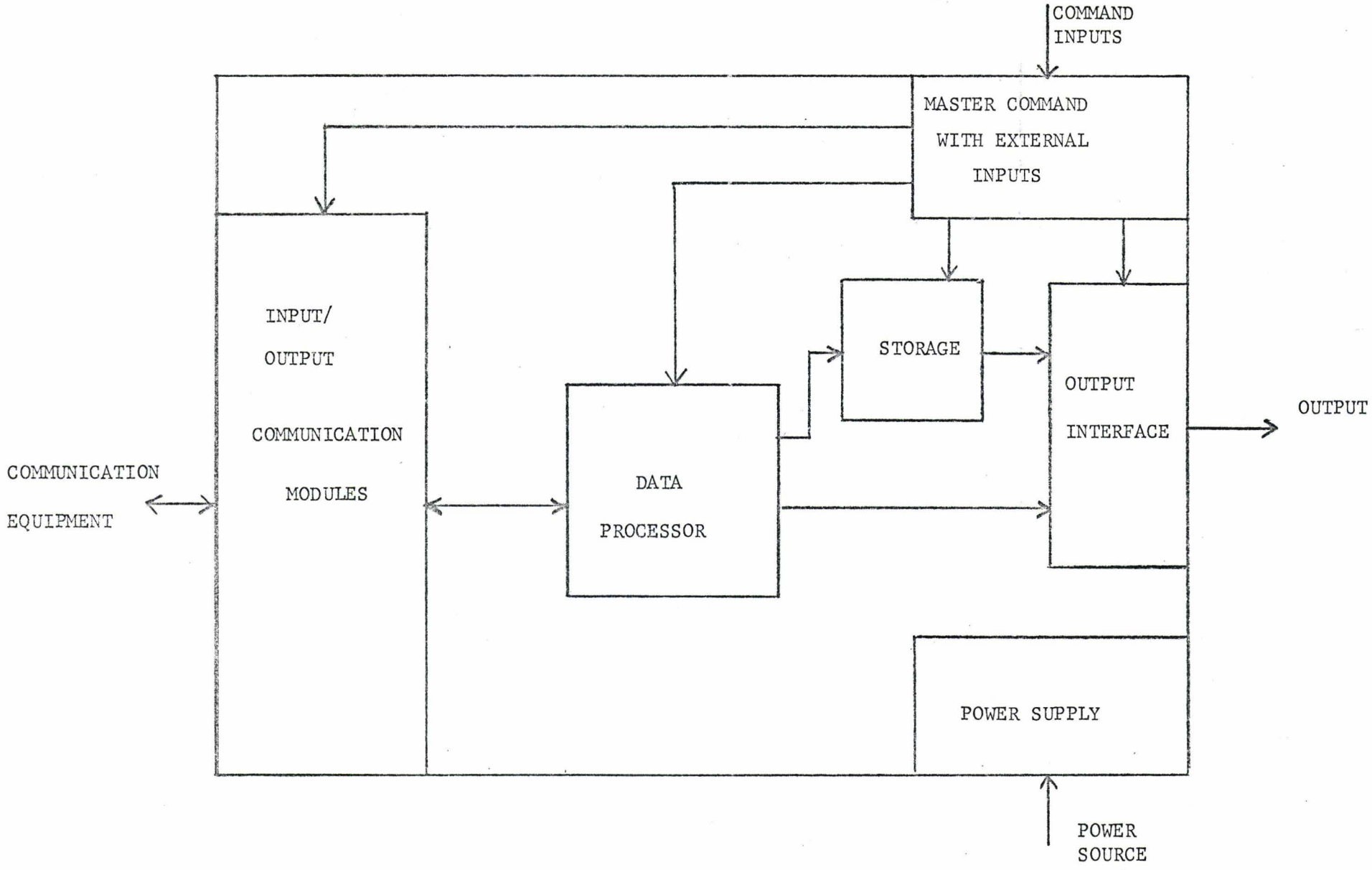


Figure 9. Base Electronics Unit - TDM/Digital Transmission

8) The number of sensors accommodated is primarily a function of the conditioning electronics provided.
9) Remote station types can readily be mixed.

e. Sensor Conditioning

The sensor conditioning electronics interfaces with the various environmental sensors and conditions this input to provide a telemetry system compatible output which properly represents the environmental parameter. Each sensor type will generally require different conditioning; sensor and conditioning development would be closely related. Sensors providing an analog variable output will require amplification, filtering and scaling to an output range of voltage. Digital sensors will require minimal signal conditioning and digital accumulation, period averaging, or code conversion. The output range will be normalized to correspond to digital words 0 - 1000, 0 - 1024, etc.

Regarding analog sensor conditioning, it should be mentioned that analog electronics are subject to variations induced by temperature excursions, by component aging and by power supply fluctuations. Further, analog circuit failure modes are not as abrupt as digital component failure; an emphasis toward digital sensors and digital conditioning could result in increased reliability and maintainability.

Flammability station sensor conditioning would be straightforward since each primary parameter list entry requires transmission of only one sensor data point. Minimum control and filtering requirements exist. Fuel moisture and fuel temperature sensor outputs will not be rapidly varying quantities; a simple sample at time of interrogation should adequately represent the data required. It should be mentioned that the possibility exists that sensor conditioning electronics could be multiplexed to service the four fuel moisture analogs. The economic feasibility can be evaluated in terms of conditioning-vs-multiplex costs.

The relatively long wind speed run suggests digital implementation. A wind speed sensor providing a pulse rate proportional to wind speed might be used. Electronic equipment would consist of a continuously operating accumulator

transferred to a buffer at hourly intervals. Analog conditioning does not seem advisable due to the very long averaging time period.

Fire Weather conditioning is more sophisticated in terms of timing, control, and the type of readings required. Areas of expected difficulty include min/max readings which are expected to require sourcing two data points. This may require using two sensor conditioning cards to be compatible with existing electronic multiplexing systems. Further, reset and anticipated timing (sampling) requirements will impose demands for control and timing which may not be readily attainable.

As a crude initial estimate it is expected that the flammability station will require six sensor conditioning cards to satisfy the primary parameter requirements and a timing pulse at hourly intervals may be required. The flammability station will require perhaps 15 sensor conditioning cards; control requirements will include reset of 24 hours min/max and accumulation/duration functions plus perhaps sampling for these parameters.

Power requirements for sensor conditioning electronics which operate continuously can be minimized by implementing digital functions with CMOS or low power TTL. Analog conditioning using micropower operational amplifiers would also be advisable. Reliability of conditioning electronics can be optimized by utilizing high reliability components. Appropriate standards have been established in military and aerospace programs.

f. Control/Command Requirements

Two types of control/command requirements may exist at the remote station location. One set of control and timing functions would be required on a continuous 24 hour per day basis to permit certain sensor and conditioning electronics to function. Another set of control or timing functions would be necessary to complete the interrogation cycle.

Continuous timing functions required by the fire weather station might include sampling commands for the min/max temperature and relative humidity sensors, timing marks for the precipitation duration sensor, and timing pulses for the 1 hour wind speed run. The flammability station could require wind speed run timing pulses.

A remote station with limited power resources would typically be in a minimum power state; that is, only the sensors and sensor electronics continuously operating plus the command receiver and perhaps the I.D. and command decoder would be powered. An interrogation cycle requires the execution of the following sequence. The command/control module would generate the timing and control signals required to execute the response to each of the commands.

COMMAND	REMOTE STATION RESPONSE
1. Prepare to Interrogate	Power is applied to station electronics and sensors to acquire environmental data.
2. Interrogate	Sensor data is staticized and transmitted; data from one sensor or the entire data set could be transmitted.
3. Housekeeping	After successful completion of the transfer of data, certain housekeeping functions may be required. For example, 24 hour min/max temperature and relative humidity, 24 hour precipitation duration and accumulation sensors would be reset at certain interrogation times.
4. Interrogation Complete	The station would be returned to a minimum power configuration.

g. Base/Remote Polling Implementation

The philosophy of implementing base station control over the remote station can vary from a master/slave polling organization in which the remote station responds

with a single, specific action to a base station command, to a network organization in which the remote station is entirely self programmed and requires and accepts no base station commands. The remote station may acknowledge, by transmission, all or some of the base station commands.

1) The first master/slave organization with positive acknowledgement requires no remote station sequential programming. The base station transmits a message containing the remote station I.D. and a command. The remote station transmits its I.D. and the data requested by a command, or a message acknowledging receipt of the command. The interrogation of a remote station would require a prepare to interrogate command, one interrogate command for each sensor, a housekeeping command, and an interrogation commpleted command.

   For a sensor list containing 13 sensors, 16 commands and 16 responses would be transmitted and with a repeatered network, time would be required for each turnaround. The total transmission time would be about four times the data transmission time. The flexibility is excellent as single sensor data can be obtained without polling an entire remote station.

2) A second master/slave organization with positive acknowledgement requires minimal remote station sequential programming. The remote station contains sufficient sequential programming that the entire sensor data list is transmitted upon receipt of the interrogate command. Prepare to interrogate, housekeeping, and interrogation complete commands remain as in the previous example. The interrogation of a remote station would require the above commands to be transmitted. For a sensor list containing 13 sensors, 4 commands, 3 acknowledgements, and a 13 sensor data list would be transmitted. Total transmission time (both ways) would be about 1.5 times the data list transmission time. Flexibility is still good as data transmission can be verified before sensors are reset and remote station acknowledgement verifies station selection, power up, sensor reset, and station power down commands.

   A variation on this operating mode would probably be acceptable for fire weather remote station control. The need for housekeeping commands is crucial here in that sensor reset commands are to be executed only once per day even though interrogation may occur a variable number of times per day. It should be mentioned that a computer program could compute daily min/max and totals given min/max readings and totals for each interrogation period.

3) A master/slave organization with maximum remote station sequential programming is also possible. In this mode of operation, receipt of a single base station command would initiate the interrogation cycle. Time delays required between the receipt of the command and actual initiation of the transfer of data would be programmed at the remote station. Housekeeping and power down command execution would automatically follow the transfer of data.

   Data transmission requirements for this case are minimal, as total data transmission would be only $\approx$ 1.15 times the remote station message for a 13 sensor data set. This mode of operation would seem quite suitable for the flammability station which does not appear to require housekeeping commands.

4) A self-programmed remote station requires maximum sequential programming and initiation of the cycle by a remote station timer. The base station no longer polls the remote stations; instead, a master timer at the remote station initiates the interrogation cycle. Problems will arise with this type of remote when operated with shared communications facilities, since contention between remotes and voice traffic, or contention between remotes (in the case of clock drift) would prevent successful data transfer. The interrogation program is insensitive to base station control.

h. Remote Station Message

The message transmitted by the remote station would include, at a minimum, the remote station I.D. and the sensor data set; additional information could include identification of sensor data by type within the transmission. Format information could include start of message characters, data delineators, and the like.

First, concerning the identification of sensor data by type, presumably the remote station data acquired for Fire Danger Rating requirements could be identified by order within the remote station message. This would hold particularly well if each of the flammability stations and each of the fire weather stations contained identical sensor complements and transmitted data in the same order. The computing facility would then be capable of decoding a remote station message

given the remote station I.D. for station type identification. Interagency data transmitted by the remote stations could be identified in a similar manner; that is, the computing facility could perform parameter identification by decoding the data message dependent on the remote station I.D. The remote collection center, of course, could also insert data type identification in the message received from the remote station.

Data could be identified by type within the remote station transmission by means of inserting special characters for sensor type identification or inserting additional standard characters for identification. Assuming character oriented transmission, the minimum character set would contain numerics for digits 0-9, a negative sign (for temperature) and perhaps one message start character. Message format characters such as space and line feed would also be required. Character oriented codes include BCD, 5 level codes, 7 level Moore ARQ, and ASCII. The BCD code requires the transmission of four data bits, plus start/stop bits and perhaps parity for each character. The character set would provide the required numerics plus a maximum of six special characters for format or sensor identification. A five level code would accommodate the numerics and provide a maximum of 22 special characters. The Moore ARQ code includes message redundancy, providing some improvement in transmission integrity with communication link induced errors.

ASCII coding probably requires excessive transmission per character, as the full character set is not required for the remote/base transmissions. The alternative to character oriented transmission would be to transmit data in binary blocks; a 10 bit block would provide 3 decimal digit resolution of a data variable. A comparison of binary encoding and BCD character encoding including start, stop, and parity bits for either method shows that binary encoding would result in the transmission of 14 bits while BCD encoding would source 23 bits for the three digit message. If data is to be type identified, binary transmission would require 28 bits and BCD character transmission would require 30 bits. Similarily, binary message transmission is inefficient if format information is to be included.

i. Data Transmission Error Control Encoding

Two types of error control procedures are possible; either forward error correction or error detection plus retransmission could be used. The method of error correction selected will be based on a compromise between remote station complexity and transmission throughput requirements. Error detection with retransmission will require the base station to reinterrogate the remote station. The detection of errors could occur either at the remote collection center or within the computing network.

Error control encoding procedures include parity check encoding, cyclic coding, and redundant message transmission. Block parity encoding requires a minimum of hardware at the remote station, but is not effective in detecting burst errors. Cyclic codes, such as the Bose-Chaudhuri code, are effective in the detection of such errors; an 8 bit check group will detect up to 100% of burst errors of 8 bits or less. The encoding required is considerably more complex than that for simple parity. Transmitting an 8-bit check group per message block would result in halving the data throughput rate under error free conditions. A minimum of two transmissions is required for error detection by redundant transmission but essentially no extra remote station hardware is required.

The simplest form of forward error correction would require a minimum of triple message transmission. A processor would compare received messages and perform a majority decision. If the computing center performed the check, no real increase in remote or base station complexity would be required. A second form of correction would require two transmissions of messages plus parity and the messages would be compared bit by bit. If complete agreement were obtained, either message would be accepted; if not, the message satisfying parity would be accepted. If neither message satisfied parity, other actions would be required. Once again, if the computing center performed the comparison, no real increase in complexity of remote or base station would result.

The effectiveness of the methods mentioned will be dependent on the exact error behavior of the communications channel; applicability will be dependent on the remote network equipment used. The fact that redundant transmission of messages requires no increase in remote station equipment is of prime importance.

j. Modulation Systems for Data Transmission

Only the modulation/demodulation techniques resulting in a voice bandwidth and voice frequency range signal will be discussed. These methods would be compatible with telephone line communication links, voice oriented microwave links, and voice oriented VHF/UHF radio communications networks. Direct modulation schemes (direct modulation of a transmitting oscillator) are probably not feasible in terms of frequency stability requirements.

Binary modulation techniques would include amplitude-shift-keying (ASK), frequency-shift-keying (FSK), and phase-shift-keying (PSK). Phase shift keying offers the best performance in terms of required signal to noise ratios; the equipment is, however, relatively complex and is oriented toward synchronous transmission. Frequency-shift-keying requires an increase in signal/noise ($\approx$3dB over PSK), but is readily implemented and is compatible with asynchronous data transmission. Performance is superior to amplitude shift keying. Data transmission using FSK is relatively insensitive to signal level variation; that is, if the signal/noise ratio remains above a critical level, essentially error-free transmission can be obtained. FSK modems may be obtained as complete units contained on a single printed circuit card.

Other than binary modulation could be used. In general, however, these modulation techniques are more complex and as a result more expensive than the mentioned binary approaches. Further, the m-ary amplitude, frequency, and phase encoded systems are most suited to synchronous transmissions over relatively noise-free communications facilities.

k. Communication Interface

The functional requirement is to provide an interface which is compatible in terms of signal bandwidth and level with the communications subsystem. Further, the interface must satisfy the terminal requirements established by the communications subsystem. The Satellite Data Collection Systems will require special equipments, and are specifically excluded from further discussions in this section.

Time division multiplexed remote station electronics providing digital data encoding will require a modem function for data transmission. The FDM systems and the TDM/analog systems will require level setting to provide an output level compatible with the communication subsystem. All implementations will require control/command message reception. A modem function will likely be required to demodulate this information to a digital format.

Operation with a common carrier switched network will require a line connect/disconnect function within the interface unit. Dedicated or privately operated switched land line networks will require a line termination. Operation with radio networks will require the communications interface to supply radio equipment compatible terminal characteristics.

3. Power Source

The power source would supply the power to satisfy remote station site equipment requirements; both continuous and interrogation related power demands would exist. Continuous requirements would include supplying power to 1) communications receiving equipment including radio receivers and command decoders, 2) sensors and sensor conditioning electronics operating on a continuous or sampled 24 hour per day basis, and 3) control functions supporting the 24 hour per day measurements. Interrogation oriented requirements would include transmitter power during data transmissions and sensor and remote electronics unit power during data acquisition and transmission. Calculation of the energy requirements for a time period requires the complete specification of remote site equipment and interrogation loading.

Presumably, to maximize station operational continuity, the primary power source would be a storage battery. This source could be recharged by equipments including wind driven generators, solar panels, thermo-electric generators (propane, solar or nuclear), and AC power line, or a Forest Service installed land line. Most of these rechargers would not provide a continuously reliable output; the primary power source would need to support the energy requirements of the remote station over a period of time. An extremely crude estimate of flammability station energy requirements assumes that six sensors are present, four interrogations are

required per day, and 10 seconds of data transmission occur per interrogation. Computing Development of Canada equipment (Phi Tran) power requirements would result in a six month energy requirement of 130 ampere-hours at 12V or 1560 watt hours. Nearly all of this energy would be dissipated in the standby mode.

4. Communication Equipment

The communication equipment required external to the Remote Electronics Unit would include a Satellite Data Collection Platform and radio set, and a radio transceiver and antenna for use with radio communication networks. The antennas in either case would be exposed to the environment. These elements would then require specification to ensure operation under possibly hostile conditions. The radio transceiver required is a critical element in the communication of data. Reliability and maintainability would need to be maximized to ensure data transmission over a design maintenance period. Some moderation of operating environment could be achieved by either burying the transceiver enclosure or perhaps heating the enclosure.

5. Physical Support Equipment

The physical equipment required at the remote station site includes sensor support hardware, enclosures for the remote electronics unit, transceiver, power source, and recharging equipment support/shielding. The sensor support hardware ensures the proper exposure of the various sensors. This would include masts to facilitate wind speed and direction measurements. Certain sensors may require some shielding to obtain the specified data.

Electronic equipment enclosures provide shielding from the effects of sun, wind, precipitation, and tampering by humans and animals. The effects of extreme environmental variations may be moderated by burying the equipment enclosures or perhaps heating the enclosures. All equipments would be securely mounted in suitable positions at the station site. This might require the construction of a concrete mounting base or attachment to a mounting post.

D. COMMUNICATIONS SUBSYSTEMS

Alternative means for data collection from the remote station network include microwave radio systems, UHF/VHF radio systems, land lines, and Satellite Data Collection Systems.

1. Microwave Systems

Microwave radio systems would be expected to provide full-duplex communications capabilities over voice grade data channels. The channels would exhibit some phase jitter and frequency offset due to the modulation system utilized; single-side-band suppressed carrier modulation would produce such deficiencies. A voice channel would be dropped for remote station data acquisition. The remote station could directly interface this drop, in which case a modem function would be required for the remote station communications interface.

The voice channel drop might also interface a VHF/UHF radio system, permitting communication with perhaps multiple remote stations. Here system control information would be transmitted over the microwave system. The voice channel drop could also interface a land line type of communication network.

2. UHF/VHF Networks

UHF/VHF transmission systems could also provide the communication system function. Networks could be dedicated for remote data acquisition or could be shared with voice traffic. Interagency rules and regulations have been established for automated remote data acquisition by radio; compliance in all respects is essential. Data acquisition with base station controlled polling of remote stations would probably simplify the network design and properly implemented polling would minimize contention problems between network users. In a complex network, the base station would provide the necessary control functions to establish communications with a remote station. This might require a set of commands to select a backbone channel, select a repeater frequency, and enable a tone encoder. The remote station would be equipped with a radio transceiver and tone select equipment compatible with the

network. Signal quality requirements would limit remote station placement and emphasize error control procedures. Reliable operation of the network would be contingent on positive control of remote station transmission. Relatively lengthy remote station I.D. codes would aid in preventing false transmissions. A fail-safe redundant method of control of station emissions would seem advisable. The actual implementation of the network is dependent on the station density, station placement, tolerable interrogation delays, and base station (network control point) capabilities.

3. Forest Level Radio Networks

The applicability of the Forest Level Radio Network for remote station communications will depend on several factors, including the following:

a. Signal quality requirements for data transmission are somewhat higher than for voice communications; a study of the radio system output signal to noise characteristics achievable with remote station transmitters and antennas would be required. The area of acceptable signal coverage may limit remote station placement.
b. Traffic control procedures must be established to positively dedicate a voice channel during remote station network communications and the time required to establish the channel must be acceptable in terms of required system response time.
c. The traffic increase imposed by the remote station network must be acceptable in terms of increased voice traffic waiting times.

The remote station transmitter output power is expected to be limited by the power source available at the remote station; an output of 5-7 watts is probably realistic. The antenna used (at VHF or UHF) could be expected to provide on the order of 10dB of gain. The effective power, then, may be comparable to that achieved with mobile transceivers in the 50 watt class. Signal quality may be more affected by interference from other users than from background sources.

Apparently, the nature of the Forest Radio Network varies considerably from region to region and forest to forest. Networks existing include single frequency systems with no tone equipment and multiple frequency tone equipped networks. The remote station transceiver would be compatible with the radio equipment present in the forest,and the base station, hopefully, would share the radio equipment at a network control point. The control point might be at the Forest Supervisor level, or at the District Ranger level.

Radio discipline could consist of a set of rules reserving set periods of time for data acquisition. During low voice traffic periods, the control point radio equipment would be dedicated to the base station. The base would select the proper operating frequency and tone channel to access a remote station. Once the link was established, the remote I.D. and command would be transmitted.

In periods of heavier voice traffic, a radio operator would presumably control the radio equipment. The base station could generate an interrupt (in the form of a light, tone, etc.) at the required time for remote interrogation. The operator would broadcast a general call for radio silence, to be broken by him, during his next transmission; the radio system would then be dedicated to the base station. Remote interrogation could proceed in a burst mode for perhaps two minutes, with about ten seconds required per flammability station remote at teletype rates using doubly redundant transmission. Voice traffic would be aware of the data traffic and completion of the interrogation task would result in extinguishing the indicator. The operator would then assume control.

Interference between voice traffic and data traffic could be minimized by several methods. Tone select equipment could be installed with the remote stations; a unique set of tones would be used for the remotes. A data-over-voice approach could be used in which base station initiated data signalling occurs above 2000 Hz. Voice frequencies would be restricted to $\leq$ 2000 Hz. Fail-safe transmitter controls could be included at the remote stations. A timer, for example, could enable transmitter power for only a fixed time after base station interrogation. The traffic loading increase due to data transmissions could be minimized by

increasing data transmission rates; this would require a base station capable of buffering the remote station message. That is, the remote/base transmissions would be optimized and buffering and/or code conversions might be required to provide the desired remote collection center output message.

4. Land Lines

The land line classification would include voice-grade and non-voice-grade lines; the line could be provided by common carriers or the Forest Service. The line connections could be dedicated to the remote station network or could be established through a message switching center.

It is expected that voice grade lines would be compatible with remote/base station communication requirements. Readily available card type modems would provide voice bandwidth compatible data encoding. Utilization of non-voice grade lines might restrict attainable data rates; remote stations reporting in a digital format could be modified, if necessary, to obtain compatibility.

Operation with the common carrier switched network requires the base station to establish a line connection to the remote. An autodialer controlled by the base station and a line connect unit at the remote station would be required. Appropriate modems would transfer data and remote station I.D. transmission would verify the connection.

If line connections are dedicated at the remote station locations, several alternatives are possible. The lines could be of a multidrop nature, interconnecting several remote stations. The base station would connect to the multidrop line and remotes would be polled in a time-sequential manner by transmission of remote station I.D.'s and commands. Narrowband FDM equipment could be installed on a voice-grade multidrop to permit simultaneous reporting by the remotes but this would be more expensive than the polled sequential approach. A dedicated line could be installed from each remote (station) to a switching center and the base station would then control the selection of the remote station line. Remote station transmissions including identification would serve to verify the connection.

5. Satellite Data Collection

Data collection utilizing a satellite network will require a specialized Data Collection Platform at the remote station site. The data down-link will be to a limited number of ground stations, by-passing the remote collection centers. Either polar orbiting ERTS type satellites or geosynchronous equatorial station-keeping satellites could be used.

ERTS A&B orbits are approximately circular at a height of 492 nautical miles and the scanning path is repeated every 18 days. The experimental payload includes a Data Collection System capable of acquiring data from 1000 fixed low power platforms every 12 hours. The Data Collection System requires Data Collection Platforms at the remote locations; this platform is designed to accept data in digital and analog form. Data are encoded and transmitted in bursts and the information bit rate of 2.5Kbs is encoded for error control resulting in a symbol rate of 5Kbs. Information bursts are of a 38 millisecond duration, occuring every three minutes and data is transmitted using a 5 watt transmitter operating at 401.5 MHz. The satellite equipment receives the transmissions and converts them for down-link on the Unified S-Band system. Ground stations decode the transmissions and derive the data output.

NASA has apparently indicated that a polar orbiting satellite network could be capable of accepting data from about 10,000 remote stations where remote equipment would include a 5 watt 400 MHz transmitter. The ground station link could be S-band and ground station cost could be about $100,000.

The Synchronous Meteorological Satellite (NASA/NOAA) includes a Data Collection System; both land based and ocean buoy Data Collection Platforms are accommodated. Buoy transmitter powers of about 20 watts are indicated and data rates are about 100 bs. The satellite is a transponder converting received transmissions at 400 MHz to Unified S-Band for ground link transmission. The Forest Service position would be that of a user. Equipments required for Satellite Data Collection Systems would be compatible with the particular system developed. Presumably, a variety of users would share the satellite facilities including ground stations.

E. REMOTE COLLECTION CENTER

The Remote Collection Center interfaces the remote stations through the communications subsystem and outputs remote station data messages to the computing network. Specification of the Remote Collection Center will require the definition of: 1) the number and types of automated remote stations to be accommodated, 2) the interrogation control capabilities, 3) the maximum interrogation rate, 4) remote station communications alternatives 5) local manual input requirements, 6) local output display requirements, 7) the collection center output message, 8) data transmission processing requirements, and 9) the operating environment, reliability, and maintainability for all Collection Center equipment.

1. Number of Automated Remote Stations

The number of automated remote stations accommodated imposes at least two requirements on the Center equipment. First the base station must generate and recognize sufficient Remote Station I.D.'s to encode and decode Remote/Base transmissions. Secondly, efficient and economical data exchange with the computing facility may require a store and forward capability. The time to interrogate automated remote stations could increase sufficiently that several burst-mode interrogation periods would be required. Communications processing to store and encode data for medium or high speed transmission would minimize line connection cost.

The types of automated stations present also would affect Center requirements; the base station would perhaps need to provide different interrogation control signals and timing to accommodate the station mix. The mixing of station message types could have implications in a minicomputer storage organization.

2. Interrogation Control Requirements

The interrogation of all remote stations could be performed at a basic rate selected by an operator and such selection would permit an adjustment of the data acquisition rate in response to seasonal variations in fire danger. Extreme

conditions might require frequent interrogations to aid in predicting fire spread, for example. The basic interrogations would be performed at times determined by a site day clock.

In addition to the basic interrogation rate, manual inputs to interrogate one remote or the entire set should be included. This capability plus a local printout would facilitate remote station maintenance, as sensor data could be monitored for acceptability. Local fire control personnel would then also be able to obtain remote station data output on demand.

The capability to accept digital inputs would permit processing equipment control of interrogation; if a single remote station can be interrogated, retransmission could be requested to replace data lost due to errors. The capability to interrogate the entire remote station set permits restoration of an entire message set or the generation of new data due to requirements determined by a central control facility. This capability could enable regional fire control personnel to initiate interrogations, etc.

Each of the communication subsystem types will require communications equipment and control interface equipment. The types of communication and the maximum number of types accommodated at a Remote Collection Center should be defined. A mixture of types may result in control requirements best satisfied by a minicomputer and control interface. Definition of the maximum interrogation rate for all remote stations will aid in defining data communications requirements with the computing/storage function. The rate could influence the implementation of message concentrating equipment, for example.

3. Manual Input Requirements

A need for local manual data entry can be presumed to exist at the Remote Collection Center; it is impractical to assume that all remote stations within a forest, for example, would become automated simultaneously. Further, some of the input data required for implementation of the complete Fire Danger Rating System are from manual observations; these data would include lightning and man-caused risk factors. Finally, data input requirements could exist for general computing users outside of the Fire Danger Rating System.

4. Local Output Display Requirements

The maintenance of automated remote stations will presumably require local operator compatible display of the remote station data message. The base station output for this function will need to include message format information such as line feed and space. Presumably this output would be teleprinter compatible in code, rate, and output level. Straightforward identification of the data by type should be possible and data output as displayed should be easily converted to engineering units.

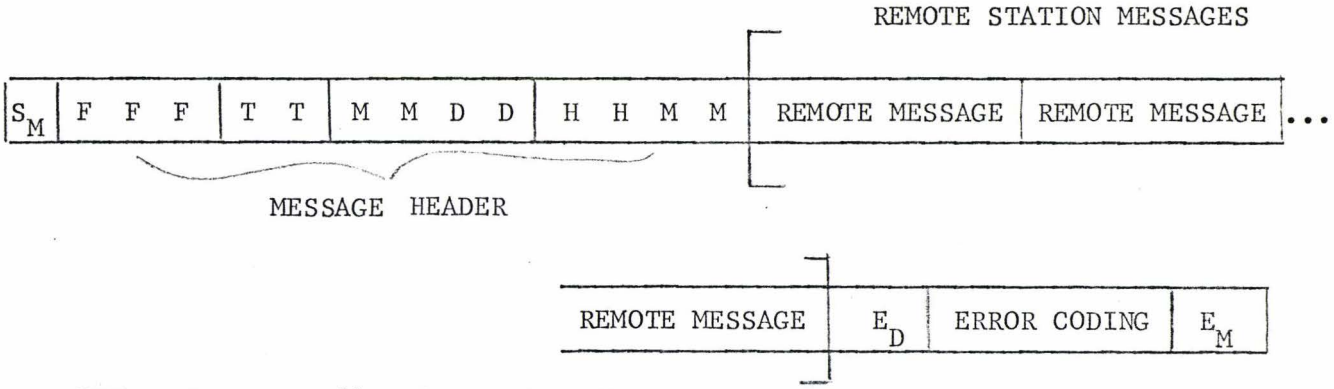
Local display of computed Fire Danger Rating System output could be required. This display could be graphic, showing the relative Burn Index or Fire Load Index by means of a light indicator panel for each of the remote stations. A printed output could be used from a teleprinter or line printer and the display unit might be shared with general computing system users.

5. Remote Collection Center Output Message

The output message from the Remote Collection Center to the computing function must contain sufficient information to permit the computing function to decode the message and identify each parameter data point by remote station source, sampling time, and parameter type. The message header assembled by the Remote Collection Center would include the Center identification code and the date and time of data acquisition. A message type identifier could also be added to explicitly declare the message type.

Each remote station data message would include, at a minimum, remote station I.D. and the station data set. Six digit remote station identifiers are used in the National Fire Danger Rating System and the Remote Station I.D.'s could contain the entire 6 digits. An alternative would be to perform a conversion to the 6 digit I.D. at the computing center. Sufficient remote I.D. would then be transmitted to permit the unique identification of a remote station within a Remote Collection Center station set. A remote station message would contain, presumably,

Fire Danger and non-Fire Danger parameter data. The data type could be declared explicitly, or could be determined at the computing center by decoding the message according to remote station I.D. and order of data appearance within the station message. An example of a possible message format (as used in CROHMS) follows:



FFF = Remote Collection Center I.D.

TT = Explicit Message Type Declaration

MM = Month (1-12)

DD = Day of Month (1-31) } Date

HH = Hour of Day (0-23)

MM = Minute of Hour (0-59) } Time

S_M = Message Start Character

E_D = End Data Character

E_M = End Message Character

Block error encoding is assumed in the example.

Example of "Minimum" Remote Station Message:

S_M	R R R	S D D D	S D D D	...	S D D D	S D D D

RRR = Remote Station I.D.

S = Space or Sign (Data Delineator)

DDD = 3 Digit Representation of Data

Example of Remote Station Message - Explicit Data I.D.

S_M	R	R	R	R	R	/	P	P	D	D	D	D	/	P	P	D	D	D	D	...	P	P	D	D	D	/

RRRRRR = Explicit 6 Digit I.D.

PP = Parameter Type Declaration

DDD = 4 Digit Data Representation

/ = Message Delineator

Estimate of remote collection center message can be carried out as follows:

Remote Station Message: Assume	3 Character I.D.	
	4 Characters/sensor	
Flammability Station:	I.D.	3
	6 sensors x 4	24
		27 characters/message
Fire Weather:	I.D.	3
	6 sensors x 4	24 (Flammability)
	5 sensors x 4	20 (single readings)
	2 sensors x 8	16 (double entries)
		63 characters/message

ESTIMATED FOREST LEVEL REMOTE COLLECTION CENTER DATA OUTPUT - NO REDUNDANCY

	"TYPICAL"		"MAXIMUM"	
	FLAM.	F.W.	FLAM.	F.W.
Stations/District	5	1	10	3
Districts/Forest	5	5	8	8
Stations/Forest	25	5	80	24
Char./Data Trans.	27	63	27	63
Char./Trans · For.	675	315	2160	1512
Char./Trans · For.	990		3672	
Center ID/Time/Date	22		22	
Time to Transmit - 100 wpm	≈ 2.0 min.		≈ 7.5 min.	

6. Data Transmission Processing Requirements

The requirement for data processing for transmission will be influenced by the number and types of remote stations, the types and numbers of sensors, the maximum station interrogation rate, error control procedures, and data transmission capability. The Collection Center message length will also be influenced by these factors. Efficient data transmission may require the removal of Remote Station message redundancy, storage to reduce line connect time, and an increase in transmission rate above teleprinter levels. Further processing could identify invalid sensor data and flag this data; the computing center could then substitute data from redundant stations.

7. Common Equipment Requirements

The operating environmental range, reliability requirements, and maintenance requirements would need to be determined for the Collection Center Equipment. Presumably, the equipment would be installed in an office environment to permit interaction with the communication equipment and personnel so that a room temperature condition could be assumed. Accessibility of the equipment for maintenance should permit relatively continuous operation with moderate reliability specifications.

8. Remote Collection Center Functional Requirements

The functional elements required at the Remote Collection Center include communications equipment, a base electronics unit, local data input equipment, local display equipment, and data transmission processing equipment.

a. Communication Equipment

Communication equipment installed at the Remote Collection Center would include the types required to establish communications with the various remote stations. Land line, microwave, and VHF/UHF equipment could be required. Land line

equipments required would include an autodialer function to establish a connection to a remote station utilizing a switched network. Privately operated switching equipment could be included on site.

Communications utilizing radio networks would require a radio transceiver and antenna. If the radio network is dedicated for remote data acquisition, the base station will positively control the facility, providing all required control signals. Communications utilizing a shared radio facility will require a control function which would dedicate the radio system during the time allocated for data acquisition. During this period the base station will positively control the radio equipment.

b. Base Electronics Unit

The base electronics unit controls the communication equipment to establish communications with the automated remote stations. The unit also must source transmissions to remote stations; remote station I.D. and commands are transmitted to control the interrogation process. Data transmissions from remote stations are decoded and converted to a data processing equipment compatible output. The capabilities of this unit must conform to the requirements established for the Remote Collection Center; the unit would likely be implemented as either a hard wired specialized controller with minimal processing capability, or could be realized using a minicomputer with a specialized interface unit to emulate the required base station terminal characteristics.

It should be noted that an evolutionary implementation of the remote station network could utilize a simple hard wired controller for the base electronics unit when requirements were minimal. When network requirements increased the controllers could be modified to perform the interface function with the minicomputers.

c. Remote Collection Center - "Minimum" Configuration

A minimum equipment configuration, which would accommodate automated remote station data and provide local data input/output is indicated in Figure 10. The base station would be presumed to possess limited control capabilities, accommodating perhaps 10-20 remote stations requiring minimal control information. Restricted communication interfacing would be provided. The base station output would be teleprinter compatible; output would be ASCII coded and provide format information for teleprinter control. Local display of remotely sensed data would be provided by a teleprinter. Data transmissions to the computing center would require the preparation of a punched tape and transfer to the send/receive unit. Minimal demands would be placed on the computing facility; redundant remote station message acquisition and transmission could be used for error control. Computing function output would be displayed through the send/receive unit.

d. Remote Collection Center - Minicomputer Function

Remote collection center equipment including a minicomputer is shown in Figure 11; communication equipment interface capability is expanded by installation of a controller at the mini I/O interface. The base electronics unit performs minimal processing to permit data exchange between the mini and the communications equipment. A code conversion plus a modem function would be required. Local input and output requirements would be satisfied with, for example, a teleprinter. The minicomputer performs data communications processing to interface a medium/high speed modem if operation over a switched voice band network is assumed.

Remote station control capability would be excellent since the number of stations accommodated would be dependent on memory buffer storage and could presumably be expanded with requirements. The interrogation control program would be stored in memory; different station types could be efficiently mixed within the interrogation sequence. Communications equipment control capability should also be excellent.

Remote/base data communications error control procedures can be efficiently implemented; remote station error control encoding can be used to reduce error rates by reinterrogation of remotes and by processing transmitted redundancy for forward correction. Limited data reasonableness tests could be performed after transmission error elimination and out-of-range data conditions could be identified and flags

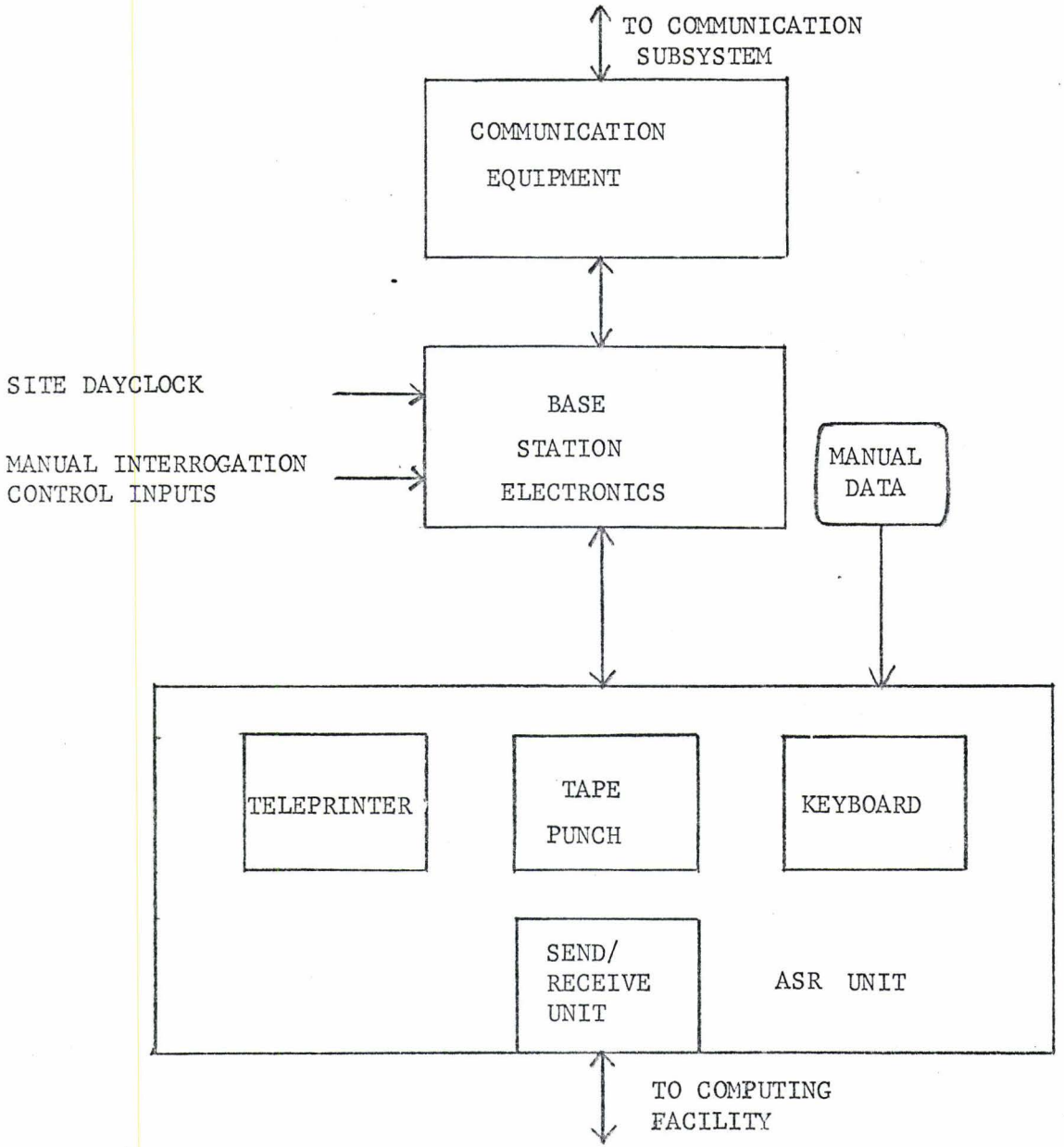


Figure 10. "Minimum" Equipment Configuration - Remote Collection Center

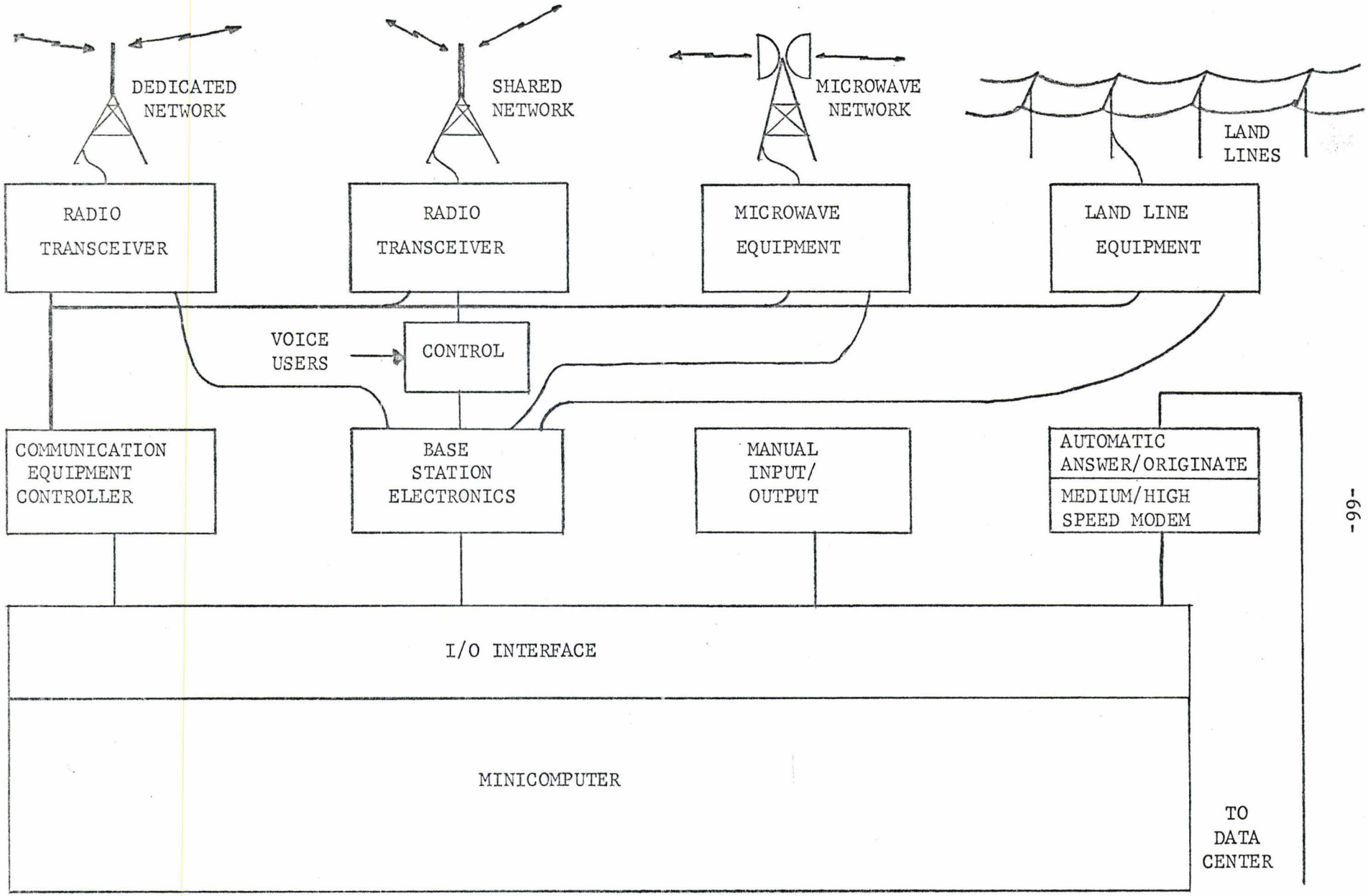


Figure 11. Minicomputer Equipment Configuration
Remote Collection Center

generated. Data processing could include conversion of remotely sensed data to engineering units for output. Limited linearization of data, scaling of data, and conversion to engineering units could be expected.

Data messages from the remote stations could be enhanced for output and data could be inserted to identify remote station data by type. Units could be appended for local output. Operations to increase data transmission efficiency could be performed. A Collection Center Message Record could be assembled from burst mode interrogations to reduce line connect time. The transmission rate would be enhanced by removing the restriction for teleprinter compatible output. Message packing, by eliminating asynchronous control bits, could be performed to utilize synchronous data transmission to and from the computing facility.

F. COMPUTING/STORAGE FUNCTION

1. Definition of Requirements

Figure 12 shows the data input source set expected for the Fire Danger Monitoring Network. The computing function may be required to accept data from the Forest Service Remote Collection Centers and from interagency networks. The data sources would include manual and automated station data. The incoming data messages will be buffered and checked for transmission errors and reinterrogation may be required to replace bad data. Message redundancy would be used to implement forward error correction. The messages would then be decoded according to system rules and Fire Danger data would be stripped from the messages. Data might be converted to a program compatible set of units and data reasonableness tests would be performed. Invalid data would be replaced by utilization of archival data or by substitution of averaged data from adjacent station records. Data from redundant stations could be used. Data alarm conditions would also produce a record for station maintenance, etc. Presumably, a complete data set would then be available from which an input data file would be assembled.

Data from the input data file and from an archival store (Central Data Base) would form the input to the operational version of FIRDAT; the computed output would be stored in an output buffer and also would be stored in the Central Data Base. Critical data input and output would be stored in a Critical File which would be used to permit system recovery in case of equipment failure.

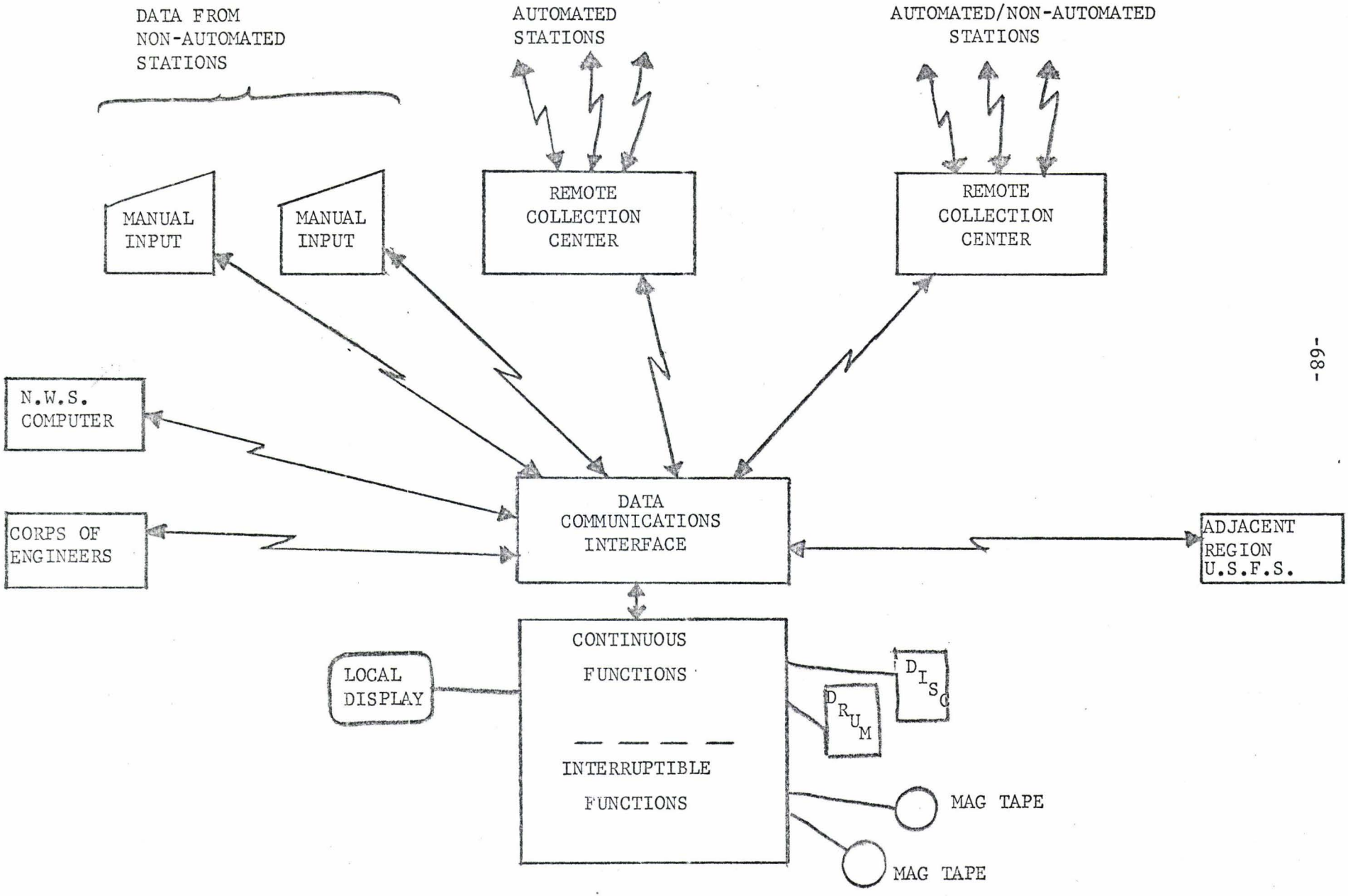


Figure 12. Computing/Storage Function

The output buffer contents would be distributed to the area sourcing the data; in addition output would perhaps be provided to the Regional Fire Control Dispatcher. Secondary computer system functions would include the distribution of non-Fire Danger data to interested Governmental Agencies. Requests for Fire Danger Computation Output would be processed as received from adjacent forests and regions. Routine lower priority functions could also include statistical computations of Fire Danger System inputs/outputs, computation of meteorological information, and production of maintenance summaries listing invalid data encountered during a processing cycle.

The physical implementation of the computing function will require study, in much more detail, of the exact nature of the input data set; that is, the number of Remote Collection Centers, the number of remotes per Center, the required system response time, and the maximum cyclic rate of the entire system process. The need to develop a Central Data Base, and the need to process inquiries from several forests, regions, and different agencies to obtain data from the central base would tend to favor the implementation of a Regional Storage Center. Data communications would be simplified, as requests for all data would be forwarded to the Regional Center. Computing requirements, as defined, might be integrated with general regional computing requirements; real-time Fire Danger System requirements would be given priority. Consideration will need to be given to the procedure implemented to deal with system down time; a second or redundant system might be required to maintain a continuous computing/storage function.

The choice of a Regional Computing Center would be affected by the actual availability of computing equipment. A survey will be required to establish the possible locations. Computing facilities available may include installations at Regional Headquarters and Experiment Stations while other offerings could include installations operated by government agencies. In addition time sharing networks could be utilized. More than two dozen companies offer some form of national network service, including conversational and batch processing. Single and multiple centers with single and multiple computers are present with most networks.

A few example offerings of commercial services would include Tymshare, Inc. and its TYMNET work. In this system, 100 TYMSAT minicomputers perform communications processing and are tied together via AT&T lines such that if one path to the computer is broken an alternate path is selected. Lines offered include 10, 15, 30 and 120 character/second transmission capability. The General Electric Network includes data lines in 250 cities in the U.S.; four types of service ranging from light computation to remote batch processing are offered. A Network Service (R) accommodates 10, 15 and 30 character per second terminals. The Computer Sciences Corporation network contains Univac 1108 computers in regional centers; their INFONET offers conversational time-sharing, conversational remote job entry, and remote batch access. Control Data Corporation operates the Cybernet national remote-batch network linking computer centers containing 6600 equipment. Five different priority levels on turn-around are offered. The KRONOS system provides conversational time sharing capability, with 10, 15 and 30 character per second lines offered.

2. Data Transmission Network

The data transmission from Collection Centers to the Computing Center would utilize available communications links including the common-carrier narrowband and voice bandwidth communication offerings. The Federal Telecommunication System offers a suitable low cost transmission medium. Careful definition of the data input requirements and computing system capabilities would permit the actual design of the data transmission network, with consideration needed for means of circumventing transmission network failures. A network design to optimize economy could include area data concentrators servicing several Remote Collection Centers; software packages to optimize network design exist.

It is expected that computing center output could be distributed over the same transmission network as was used for data acquisition; additionally, limited Fire Danger Rating data could be output over the Fire Control teletype network. The services presently available for data communication include WATTS, FTS, Private Line Voice services, Private Line Teleprinter services, and TWX plus Telpak A and Telpak B in some states.

Capabilities available include Telegraph Channels (75, 150 and 300 baud), Voice Grade Channels (1200, 2400, 3600, 4800 and 9600 baud) and Broad-Band Channels (19,200; 40,800; 50,000; 200,000; and 230,400 baud). The implementation of digital networks by AT&T, Western Union, MCI, and Datran may reduce transmission cost. Offerings from AT&T will include 2,400; 4,800; 9,600; 56,000 bps service. These are private line, leased offerings. The Western Union network will offer 50 and 150 baud character oriented transmission, 75 and 150 baud transparent channels, and 2400, 4800, 9600 bps, and 56 kbps rates. The Datran Communication net is based on 4800 bps channels of 2KHz bandwidth; offerings will include dial-up multiple 150 bps channels, 4800, 9600, and 14,400 bps channels and leased only 48,000 bps channels. MCI is planning a private line network; 138 different sized channels from 200 Hz to .96 MHz may be offered.

The network design could result in star, multidrop, loop and dot geometries. The networks are defined as:

Star	-	Individual lines connect the center to the remote or local terminals.
Multidrops	-	Terminals appear as drops off a single line running from the most distant terminal
Loop	-	A single line leaves the center and threads through all terminal points before returning to the center.
Dots	-	Terminals are off-network and connected to the center only on a dial-up basis.

The data transmission system could include multiplexers at the Remote Collection Centers to integrate the Remote Station Data requirements with general computing user requirements. To minimize transmission network costs, area concentrators could be used to merge data from several Remote Collection Centers for transmission to the Computing/Storage Function. The concentrators contain line control modules for input and output lines, a communication controller, and a digital computer with storage capability. Circuits can be combined and polled; messages can be converted for efficient transmission. Bit stripping, data queuing, storing and formatting

can be performed; additionally, error detection and correction can be performed. Thus, a Remote Collection Center network might be connected in a star, multidrop, loop, or dot configuration to the area concentrators.

G. ESTIMATE OF REMOTE STATION SURVIVAL PROBABILITY

1. Remote Station

The survival probability may be broken out into two separate areas: the probability of survival of each sensor (plus adapter) and the probability that the remainder of the remote station will be capable of transmitting some good data. This is logical as different numbers of sensors will be accommodated at each remote station. Further, this breakout tends to emphasize the effects of each unit's reliability. A chart as follows will be developed; RAMOS goals are assumed for estimation purposes.

		SIX MONTHS OPERATIONAL PROBABILITY	
	UNIT	U.S.F.S. GOAL	RAMOS
1.	Sensor + Adapter	P_{si}	.75
2.	Basic Electronics Unit (less adapter/power supply)	P_{eu}	.955
3.	Power Supply (AC Power)	P_{ps}	.93
4.	Radio Transceiver	P_{TR}	.35 - .7
5.	Radio Antenna	P_{A}	.90
6.	Power Pack (110W DC)	P_{pp}	.90

It is apparent in this list that the radio transceiver is one of the "weaker" items in the remote system; a .35 probability was commercially available. A RAMOS goal of .7 was set.

Examples of the calculation of remote system survivability follows:

Probability of transmitting some good data (joint survival of all but sensors/adapters)

VHF Radio/DC power pack

$P_T = P_{eu} \times P_{TR} \times P_A \times P_{pp}$ — 6 month operational probability-RAMOS reliability goals

$P_T\ (P_{TR}=.35) = .955 \times .35 \times .9 \times .9 = .27$

$P_T\ (P_{TR}=.7) = .955 \times .7 \times .9 \times .9 = .541$

Probability of Flammability Station Survival

Sensors: Fuel moisture = P_{SFM}
Fuel temperature = P_{SFT}
Wind speed = P_{SWS}

Sensor survival probability - flammability station

$P_{SFS} = (P_{SFM})^4 \times P_{SFT} \times P_{SWS}$

$(RAMOS) = (.75)^4 \times .75 \times .75 = .178$

Station survival - all sensors

$P_{FS}(P_{TR} = .35) = P_T \times P_{SFS} = .045$ — 6 month operational probability-RAMOS reliability goals

$P_{FS}(P_{TR} = .7) = P_T \times P_{SFS} = .089$

Probability of Flammability/Fire Weather Station Survival

Sensor survival probability

Flammability Function = $P_{SFS} = .178$

Fire Weather = P_{SFW}

Sensors - Wind Direction = P_{SWD}
Air Temperature = P_{ST}
Atmospheric Moisture = P_{SAM}
24 hr. Temp Min/Max = P_{STM}
24 hr. R.H. Min/Max = P_{SRHM}
24 hr. Precip. Total = P_{SPT}
24 hr. Precip. Dur. = P_{SPD}

Fire weather function = P_{SFW}

$$P_{SFW} = P_{SWD} \times P_{ST} \times P_{SAM} \times P_{STM} \times P_{SRHM} \times P_{SPT} \times P_{SPD}$$

(RAMOS) P_{SFW} $(.75) \times (.75) \times (.75) \times (.75) \times (.75) \times (.75) \times (.75) = .133$

Station Survival - 6 month operation reliability - RAMOS Goals

Flammability (all sensors - 6)

P_{FS} $(P_{TR} = .35) = .048$

P_{FS} $(P_{TR} = .7) = .096$

Fire Weather (all fire weather sensors - 7)

$P_{FW} = P_{TR} \times P_{SFW} =$

P_{FW} $(P_{TR} = .35) = .03591$

P_{FW} $(P_{TR} = .7) = .07182$

Flammability/fire weather (all sensors - 13)

$P_{FS \cdot FW} = P_{SFS} \times P_{SFW} \times P_T$

$P_{FS \cdot F_W}$ $(P_{TR} = .35) = .0059$

$P_{FS \cdot FW}$ $(P_{TR} = .7) = .0119$

If the probability of survival is redefined in terms of 1 month periods, using 6 months RAMOS goals, the following table can be developed:

Table 5. Remote Station Operational Probability

RAMOS Design Goals used for all Items	OPERATIONAL PROBABILITY AT END OF MONTH NUMBER 1	2	3	4	5	6
P_T · Prob. of transmitting some data $P_{TR} = .7$	.9027	.815	.736	.664	.599	.541
$P_{TR} = .35$	.8044	.647	.521	.419	.337	.27
6 Flammability Sensors (P_{SFS})	.75	.563	.422	.316	.237	.178
7 Fire Weather Sensors	.714	.51	.364	.259	.186	.133
13 F.W./Flam. Sensors (P_{SFW})	.533	.284	.152	.081	.043	.023
STATION OPERATIONAL PROBABILITY: ALL SENSORS FUNCTIONING						
P_{FS} - Flammability Station (P_{TR}=.7)	.677	.508	.343	.233	.158	.107
P_{FW}-Fire Weather 7 Sensors (P_{TR}=.7)	.645	.415	.267	.173	.111	.072
$P_{FW} \cdot P_{FS}$ -Fire Weather 13 Sensors (P_{TR}=.7)	.481	.231	.111	.054	.026	.012
STATION OPERATIONAL PROBABILITY: ANY ONE SENSOR						
Probability of transmitting good data from any 1 sensor	.86	.74	.637	.55	.47	.406

Even with the RAMOS 6 month design goals, only 3/4 of stations can be expected to source some data at the end of a 3 month period; 2/3 of the parameter data of one type sourced into the communications network could be expected to be usable. As was mentioned by the Forest Service, redundant stations would be provided to achieve the required network reporting density. The maintenance schedule implemented also could maximize data acquisition capability during the peak of the fire season. Maintenance at a time following the winter non-operational period and preceding the peak fire period would result in a favorable system status at the time of greatest need.

2. Repeater Network Reliability

The data path from the remote station subsystem to the base station will include the radio repeater network so that the probability of survival can be determined for each remote station/base station path. The probability is path oriented so the form will be: $P_{RN(RS,BS)} = P_{RK} \cdot P_{RL} \cdot P_{RN}$. Joint survival of several repeaters may be required in a cascade arrangement.

3. Base Station Survival

The base station subsystem contains the base electronics unit, power supplies, and communications facility. Because maintenance is more readily available, lowered operational requirements could be accommodated. The relatively controlled operating environment should increase survival probability, however. Once again, RAMOS numbers are assumed.

ITEM	OPERATIONAL PROBABILITY ONE MONTH	SIX MONTHS
1. Basic electronics unit with power supply	.97	.84
2. Radio transceiver/power supply	.89	.50
3. Radio Antenna	.97	.85

P_{BS} (1 mo) = (.97)(.89)(.97) = .837

P_{BS} (6 mo) = (.84)(.50)(.85) = .357

PART III. SCHEDULE OF TASKS AND SYSTEM DEFINITIONS FOR PHASE II

A. Detailed Data Quality Specifications

1. Parameter List Determination

   a. Accuracy
   b. Sensitivity
   c. Range
   d. Resolution

   } Over operating and non-operating environment

2. Transmission Error Control
3. Data Reporting Failure
4. Response Time Requirements

B. Remote Station Site Equipment

1. Sensors Specification
   a. Sensor Data Quality Requirements Translated from A.1. above
   b. Reliability
   c. Maintainability
   d. Physical Construction
   e. Control Requirements
2. Remote Electronics
   a. Maintainability
      (1) Period
      (2) Mean Time to Perform Maintenance
      (3) Support Equipment and Personnel
   b. Reliability
      (1) Hardware Selection
      (2) MTBF Requirement
   c. Specification of Operating and Non-Operating Environments
   d. Compatibility with A.1. above
   e. Communication Interface Flexibility
   f. Define Interrogation Requirements
   g. Error Encoding Requirements
   h. Sensor Compatibility
   i. Number of Sensors Accommodated
      (1) Flammability
      (2) Fire Weather Station
   j. Power Requirements

3. Power Source
   a. Reliability
   b. Maintainability
   c. Primary Power Source
   d. Recharging Unit
4. Communication Equipment at Remote Site
   a. Reliability Requirements
   b. Survey of Radio Transceiver and Antenna Equipment for Interface with Conventional Network
   c. Data Collection Platform and Radio Set
   d. Power Requirements
   e. Transceiver Compatibility with B.2.a. above
   f. Antenna Compatibility with B.4.a. above
   g. Fail-safe Transmitter Control
5. Physical Support Equipment at Remote Site
   a. Proper Sensor Exposure
   b. Remote Electronics Protection
      (1) Environment
      (2) Vandalism
      (3) Moderation of Environment

C. Remote Collection Center
1. Common Hardware Requirements
   a. Operating Environment
   b. Reliability
   c. Maintainability
   d. Physical Enclosures
2. Communication Equipment
   a. Land Line Equipment
      (1) Voice-grade lines,
          switched or non-switched.
      (2) Non-voice-grade lines
   b. Radio Network
      (1) Dedicated (transceiver, antenna, control interface)
      (2) Time Shared (existing radio transceiver, antenna, additional control, encoding)
   c. Microwave Network

3. Base Electronics Unit
    a. Number of Remotes
    b. Output Format
    c. Interrogation Control
        (1) Basic Interrogate Rate
        (2) Manual Controls
        (3) Digital Controls
    d. Communications Control
4. Manual Entry
    a. Fire Danger Rating System Data
    b. Additional Local Data
    c. Maintenance Requirements
5. Local Output
    a. Fire Danger System Requirements
        (1) Data Acquisition Output for Maintenance
        (2) Computed Fire Danger Indices
        (3) Hardcopy Output
        (4) Graphic Output
    b. Generalized Local Data Output
6. Communications Processing Alternatives
    a. Error Detection/Correction
    b. Data Storage/Code Conversion/Controlled Message Transfer
    c. Message Expansion
    d. Data Conversion to Engineering Units

D. Remote/Base Communications Subsystem
1. Detailed Selection and Description of Remote Sites
2. Evaluation of Suitability of Existing Networks for Data Transmission
    a. Forest Level Radio Network
    b. Existing Microwave Networks
    c. Existing Land Lines
    d. Satellite Data Collection System
    e. Existing Interagency Networks
3. Elimination of Network Deficiencies
    a. Forest by Forest Modification of Existing Facilities
    b. Review of Traffic Load Increase Due to Remote Station Data Requirements
    c. Description of Required Dedicated Networks

E. Computing Function

1. Define Total Software Requirements

a. Fire Danger Rating Data Acquisition Tasks

(1) Input Buffer Storage

(2) Data Transmission Error Control

(3) Message Decoding to Extract Fire Danger Rating Data

(4) Data Conversion to Program Compatible Units

(5) Data Reasonableness Tests and Replacement of Invalid Data

(6) Output Tasks

(a) Transmit Data to Interagency Users

(b) Alarm Condition Outputs to Identify Nonfunctioning Equipment

(c) Data File Construction

b. Fire Danger Computation

(1) Archival Record Retrieval and Data File Access

(2) Index Computation

(3) Update Archival File Including Central Data Base

(4) Update Output Buffer

c. Lower Priority Computation

(1) Statistical Analysis of Data

(2) Meteorological Processing

(3) Maintenance Record Construction

d. Data Interchange/Retrieval Control

(1) Schedule Tasks

(2) Control Access to Central Data Base

e. Fire Danger Rating System Output

(1) Distribute Indices to Source Locations

(2) Distribute Summaries, etc., to Regional Offices

2. Define Total Storage Requirements

a. Central Data Base

b. Input Data File

c. Output Data File

d. Designate Critical Data Files to Permit Recovery from System Failure

3. Definition of Computing System Requirements

a. Fire Danger Rating Input Data Set

(1) Number of Remote Collection Centers and Data Set per Collection Center

(2) Definition of Required Response Time

(3) Definition of Maximum System Interrogation Rate

b. Data Interchange

4. Evaluate Existing Computing Facilities

a. Regional Headquarters
b. Experimental Stations
} Forest Service

c. Governmental/Interagency Facilities

d. Commercial Time Sharing Networks

5. Data Transmission Requirements

a. Survey Transmission Alternatives Consistent with Items 3 and 4 above

b. Perform Selection Based on Tradeoffs of Economy, Network Reliability, and Expansion Capability

6. Processing System Integrity

a. Permissible Down Time

b. Alternative Processing Facilities

c. Recovery from Processing Failure

PART IV. SCHEDULE OF TASKS FOR PHASE III

A. Equipment Survey and Evaluation
   1. Survey of Available Sensors
      a. Evaluation Relative to Phase II Specifications
      b. Determination of Required Modification or Development
      c. Consideration of Required Support Equipment
   2. Survey of Available Base Station Electronics
      a. Evaluation Relative to Phase II Specification
      b. Determination of Required Modification or Development
   3. Survey of Available Communication Equipment
      a. Remote Station Equipment
      b. Collection Center Equipment
      c. Remote/Base Subsystem Equipment
   4. Survey of Available Power Source/Recharger Equipment
   5. Survey of Elemental Base Station Electronics
      a. Comparison with Desired Specifications
      b. Compatibility with 1.a. above
   6. Estimation of Reliability for All Surveyed Equipment
   7. Recommendation of Available Equipment
      a. Sensors
      b. Base Station Electronics
      c. Communications Equipment
      d. Power Source/Recharger Device
      e. Collection Center Equipment
   8. Recommended Modification of Equipment
      a. Performance Improvements
      b. Compatibility Requirements
      c. Reliability Deficiencies
   9. Recommended Development of New Equipment
   10. Development of Second Sources
   11. Computing Recommendations from Part III, Section E, Number 4.

B. Cost Estimates

1. Estimated Cost of Equipment Modification from A, 8 above
2. Estimated Cost of New Development from A, 9 above
3. Itemized List of Parts and Labor from Cost Estimation Methodology Section
4. Computing Costs from A, 11 above

PART V. COST ESTIMATION METHODOLOGY

The following outline is intended to serve as an initial and general guide for cost estimates for deploying and operating the Fire Danger Monitoring Network. The assumption here is that the Phase II and subsequent studies will have determined the necessary detailed specifications which must characterize the various elements in the data system in order that the system operate with adequate reliability to gather data sufficiently free from error. Because of the current commercial and government activity in remote data gathering equipment, it is likely that any development money spent may support equipment modification or redesign. The Forest Service requirements most likely to generate the need for such support include (1) the high reliability of the system components, (2) the preference for maintenance by personnel with minimum technical training, and (3) the possible sharing of the Forest Service Radio Network.

A. POSSIBLE DEVELOPMENTAL COST AREAS

1. Individual Sensor Modification or Substitution
2. Remote Station Modification for Increased Reliability
3. Addition of Unique Network Control
4. Power Source Modification
5. Provision for Fail Safe Transmitter Operation
6. Provision for On-Site Error Simulation, Maintenance Diagnostics, and Manual Entry
7. Data-Over-Voice Data Link Techniques
8. Reformat of Data at Base Station
9. Provision for Manual Entry at Base Station
10. Expansion of Remote Station Identifier Word
11. Addition of Priority Interrupt at Base Station
12. Design of Error Simulator
13. Design of Remote Station Test Device
14. Design of Portable "Manual" Remote for use with Mixed Automatic/Manual System
15. Design of Repair Depot Test Equipment
16. Design of Sensor Calibration Aids

B. SYSTEM DEPLOYMENT COSTS

1. Remote Site Selection and Surveying
2. Remote Site Preparation
   a. Construction Labor and Materials
   b. Inspection
3. Remote Station Subsystem Parts List
   a. Sensor Set Plus Conditioning Equipment
   b. Power Source and Recharging Unit
   c. Remote Electronics Unit
   d. Communication Equipment
   e. Equipment Enclosures
4. Remote Station Installation
   a. Technical Labor
   b. Calibration and Demonstration Period
   c. Equipment Breakage
   d. Site Rework if Needed
5. Communication Network
   a. Installation of New Repeaters
   b. Refurbishing Present Repeaters
   c. Field Strength and Coverage Tests
6. Base Station Site Selection
7. Base Station Site Preparation
   a. Construction Labor and Materials
   b. Power and Phone Line Installation
8. Base Station Subsystem Parts List
   a. Equipment Enclosures
   b. Communication Equipment
   c. Network Control Equipment
   d. Power Supply
   e. Manual Entry Devices
   f. Output Devices

9. Base Station Installation
   a. Technical Labor
   b. District Demonstration and Checkout Period
   c. Regional Communication Testing
10. Personnel Training
   a. Ranger Instruction
   b. Electronics Technician Training
   c. Repair Depot Personnel Training

C. OPERATING COSTS

1. Routine Parts Purchase
   a. Remote Station Replacement Parts
   b. Base Station Replacement Parts
   c. Communication Network Spare Equipment
   d. Repair Depot Inventory Replacement
   e. Power Supply Recharging Materials
2. Maintenance Expenses.
   a. Fractional Part of Electronics Technician Labor
   b. Fractional Part of Ranger Labor
   c. Repair Depot Labor
   d. Repair Depot Housing, Test Equipment
   e. Equipment Shippage

The costs of data processing and software development have been deliberately omitted for several reasons. These costs can be estimated after the Phase II study on the basis of bids from data processing companies which operate large time-sharing networks, assuming such a network would suffice. If regional computing facilities are to be used, the incremental cost of data processing due to the Fire Danger Network will be dependent on the equipment which must be added and the resulting processing load.

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